Recent results from NA61/SHINE experiment

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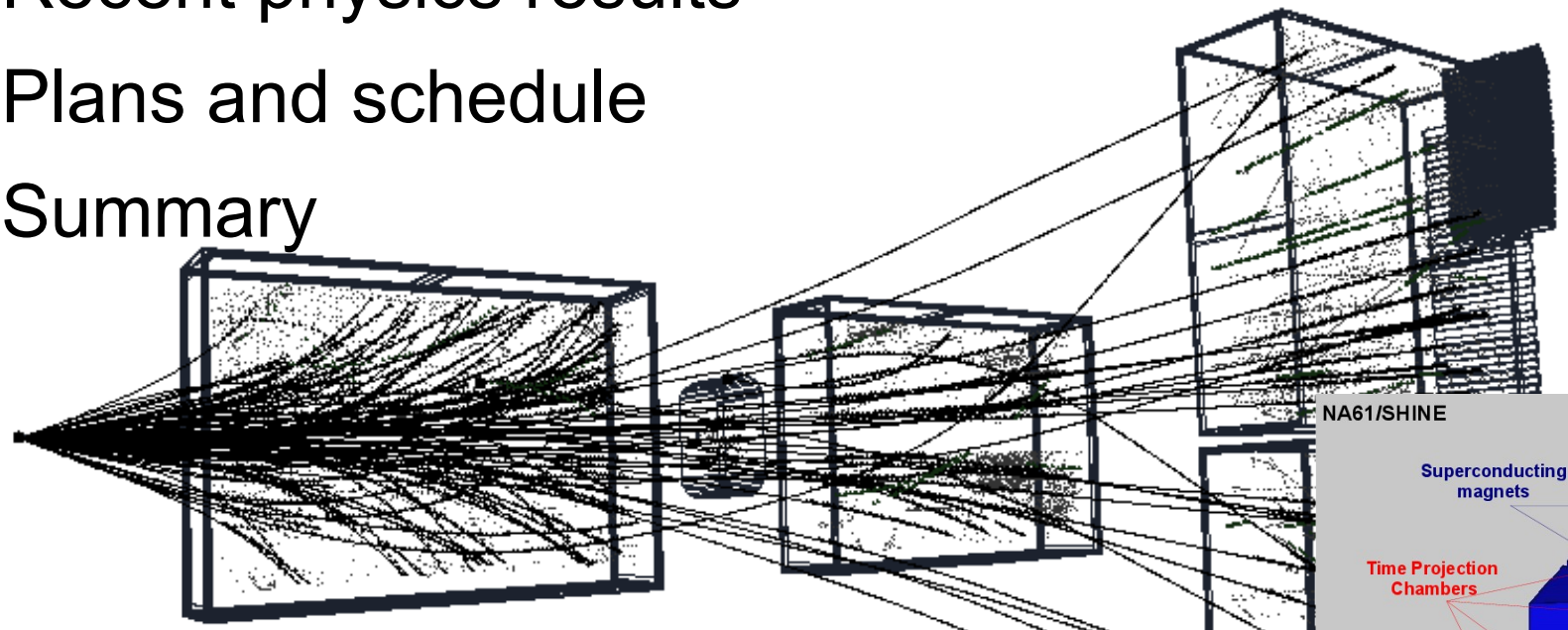
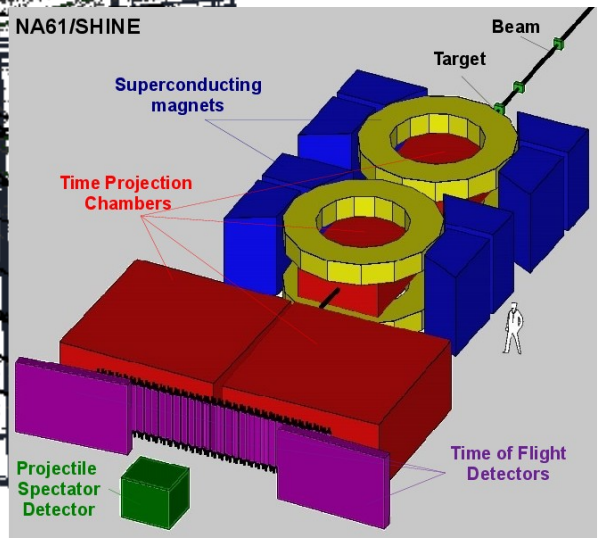
Outline

- Physics goals of NA61/SHINE experiment
- Detector layout and data taking program
- Recent physics results
- Plans and schedule
- Summary



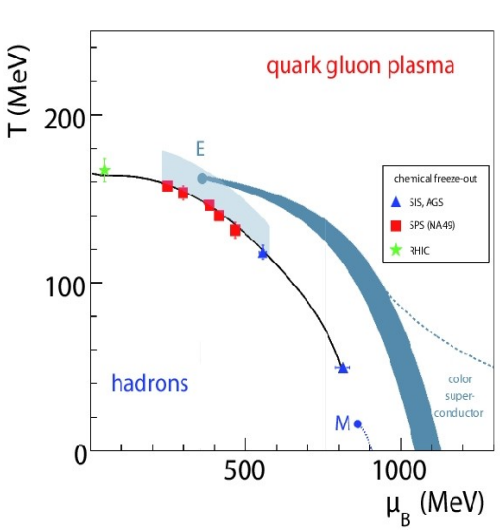


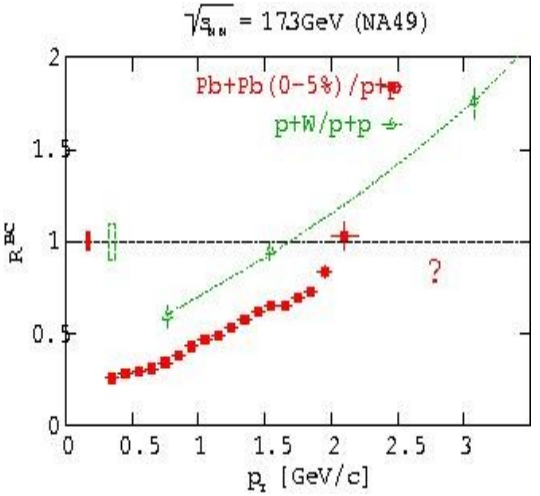
NA61: North Area 61

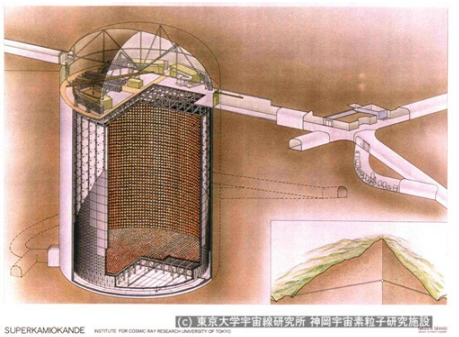
SHINE: SPS Heavy-Ion and Neutrino Experiment

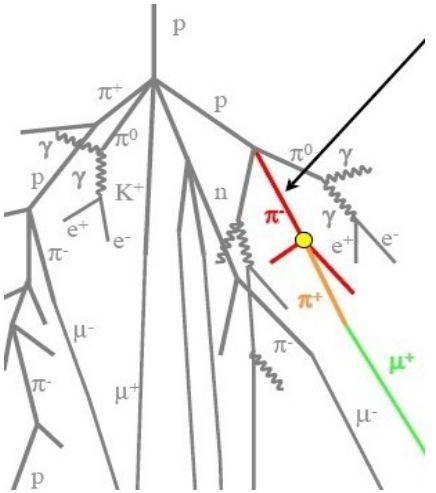
Physics goals of NA61/SHINE experiment

- NA61 is a large acceptance hadron spectrometer experiment at the CERN SPS. Main tracking components: 40m^3 TPC system.
- Main physics goals are to measure:
  - Hadronic spectra and fluctuactions in A+A for studying Onset of Deconfinement and searching for Critical Point in strong interactions, intermediate p_T physics in p+p, p+A, A+A
  - Reference hadron spectra in p+C for T2K experiment
  - Reference hadron spectra in π^-+C for the Pierre Auger Obs.



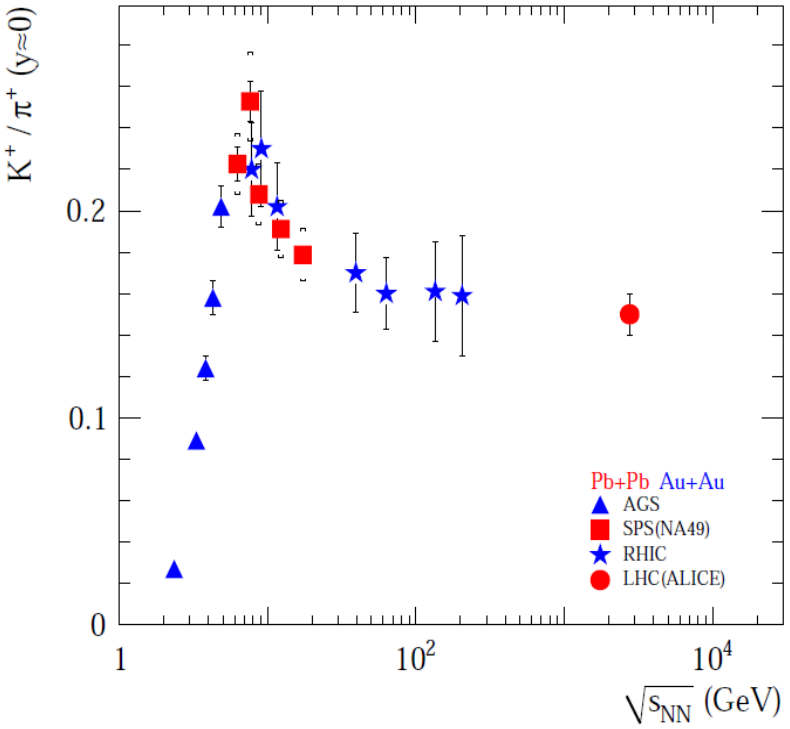


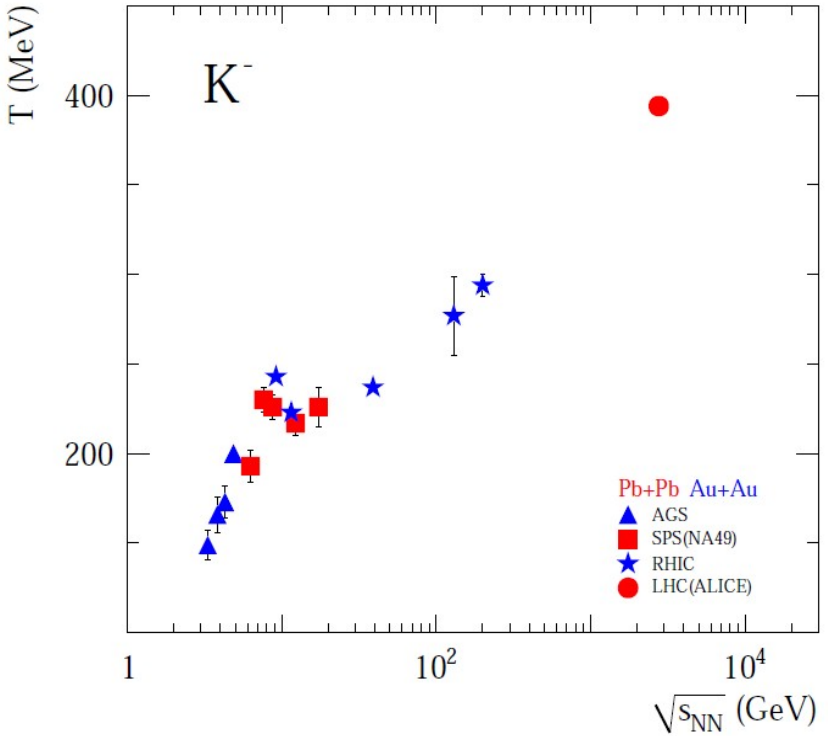




HI physics and NA61/SHINE

- Change of energy dependence of hadronic observables around SPS energies in A+A.





- Compatible explanation: decrease of strangeness carrier masses, decrease of number of strange to non-strange degrees of freedom.

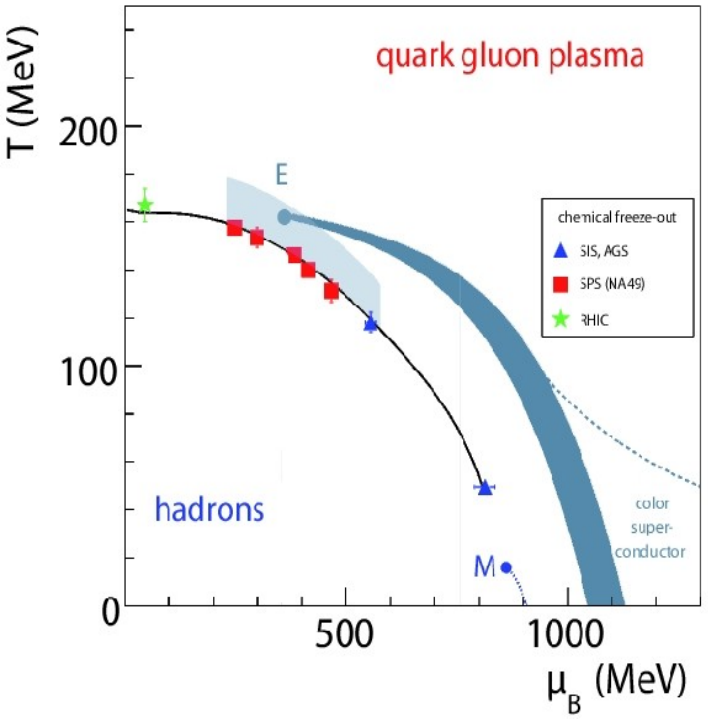
- Compatible explanation: constant temperature and pressure in mixed phase.

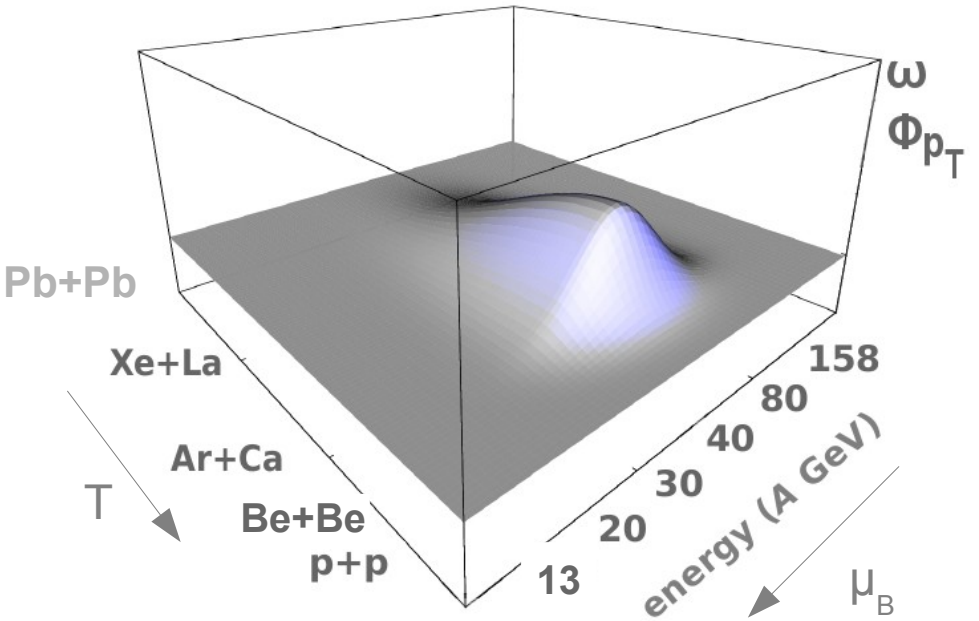
(Onset of deconfinement)

- Lattice QCD indicates existence of a critical point of strongly interacting matter at freeze-out termperatures forseen to be accessible around SPS energies.

- NA61 is searching for CP and is studying OoD by performing an E—A scan program with moderate statistics.

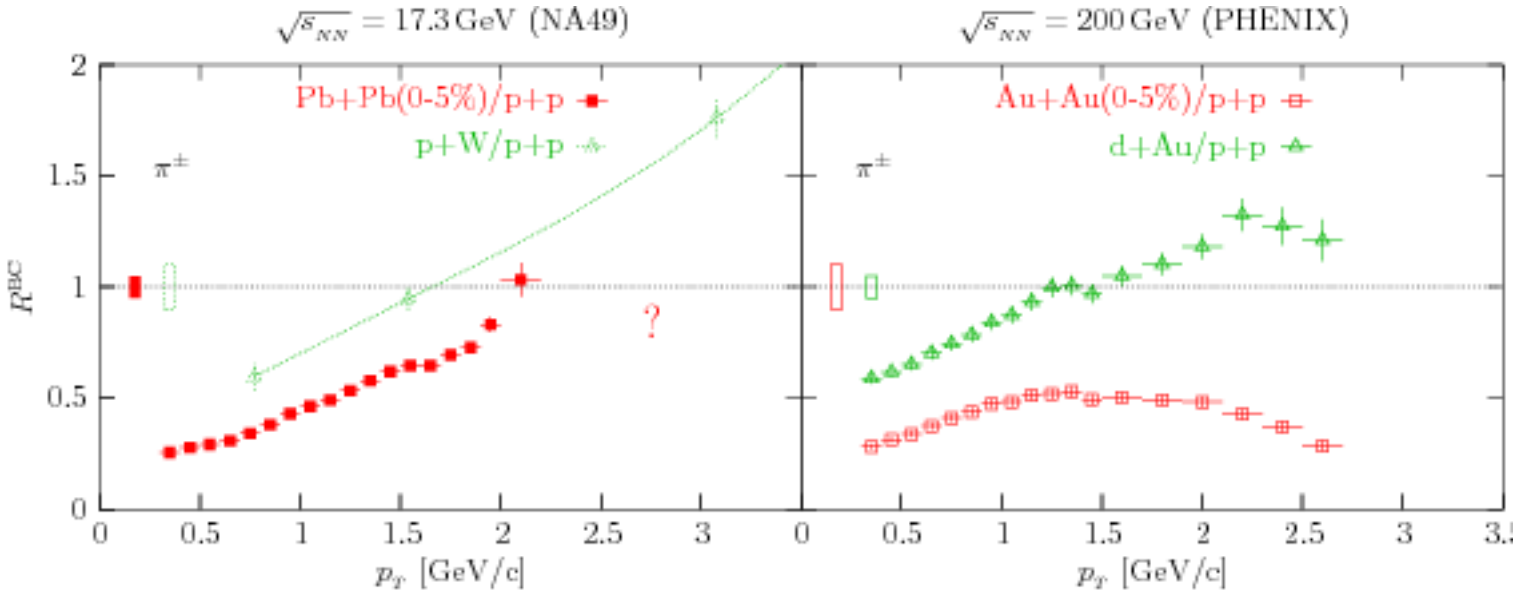
- Searching for the Critical Point of strongly interacting matter in A+A collisions.





- Lattice QCD indicates existence of a critical point of strongly interacting matter at freeze-out termperatures forseen to be accessible around SPS energies.
- In case of freeze-out close to critical point with large enough system: larger fluctuations, power-law like behavior => hill of fluctuations expected in E—A plane.
- NA61 is searching for CP and is studying OoD by performing an E—A scan program with moderate statistics.

- Medium effects in A+A: energy dependence of R_{AA} (nucl. mod. fact.)
  - Strong intermediate / high p_T hadron suppression seen at RHIC and LHC energies
  - Strong energy dependence of this effect toward SPS energies is expected



Phys.Rev. C77 034906

- NA49 measured R_{AA} at SPS energies but not to sufficiently high p_T. NA49 measured R_{CP} and sees suppression.

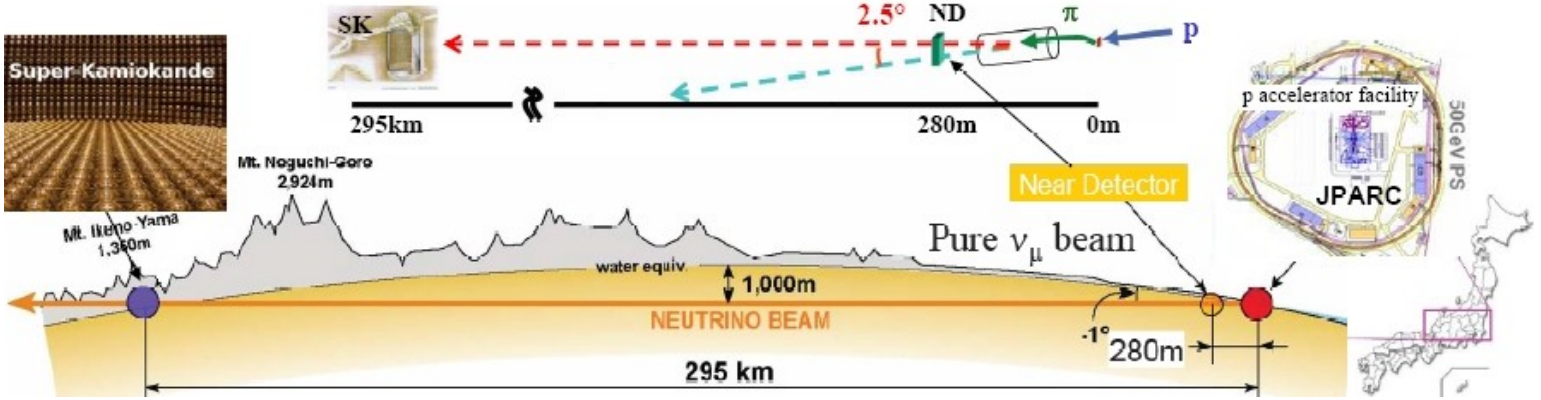
Phys.Rev. C69 034910, C74 024904

- Strong high p_T suppression seen in R_{AA} at RHIC and LHC energies.

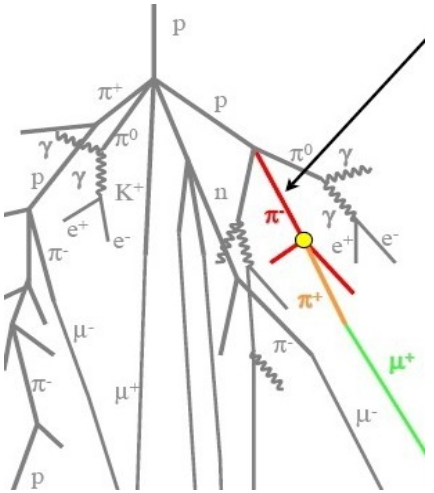
- NA61 is completing R_{AA} measurements by the high statistics p+p and p+Pb data.

Neutrino and CR physics

- In neutrino beam experiments, such as T2K, mesons are produced with a proton beam on a production target. Neutrinos are produced from decay of mesons. Precise knowledge is needed on the meson production cross section differentiated in momentum space. NA61 provides these p+A reference spectra.

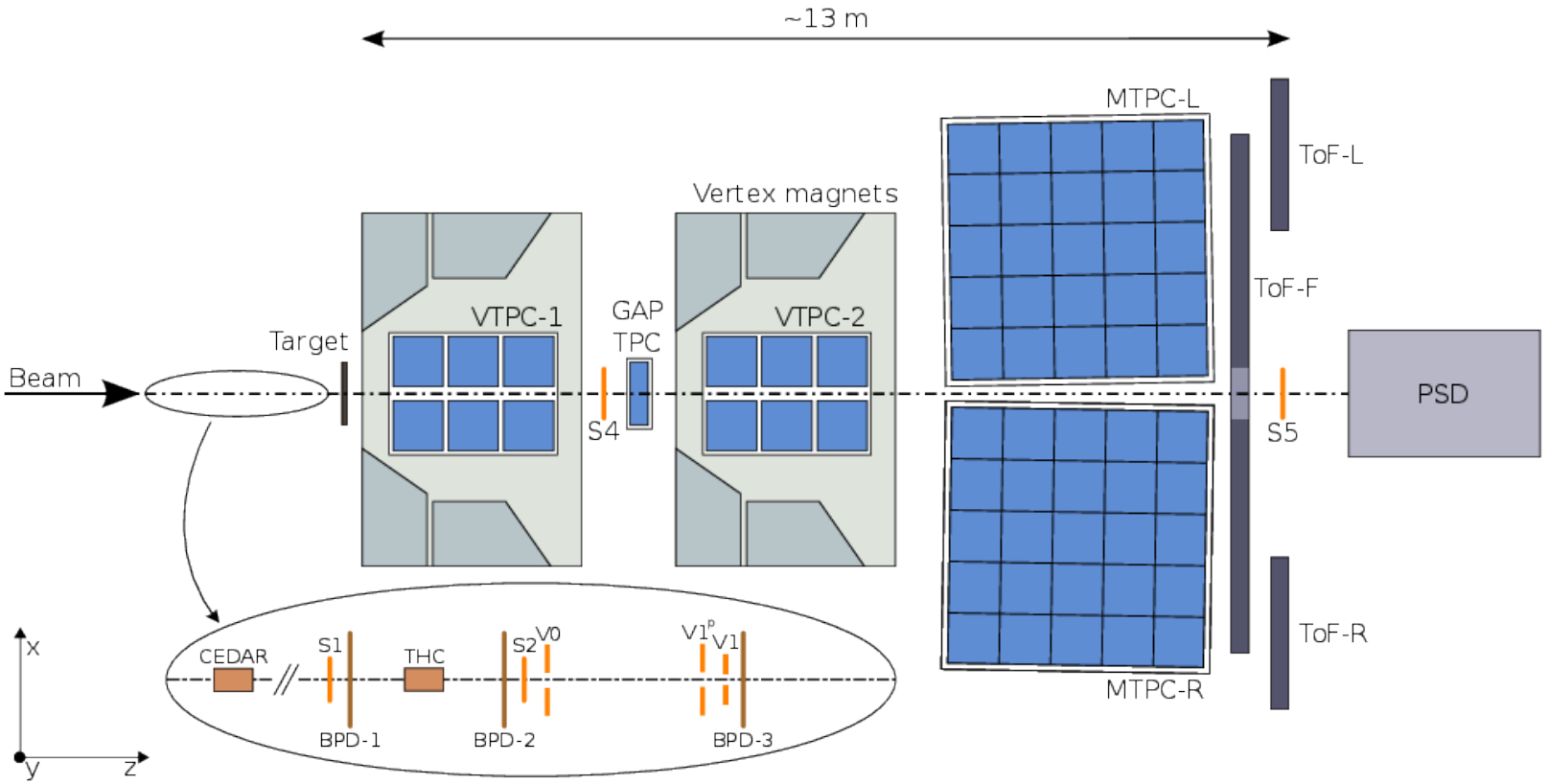


- In large coverage cosmic ray observatories, such as Pierre Auger Observatory, the modelling of cosmic air showers is most sensitive to $\pi^{\pm}/K^{\pm}$ production in $\pi^{\pm}/K^{\pm}$ + air nucleus collisions. NA61 provides precise $\pi^{\pm}/K^{\pm}$ spectra in $\pi^{\pm}/K^{\pm}$ + C collisions.

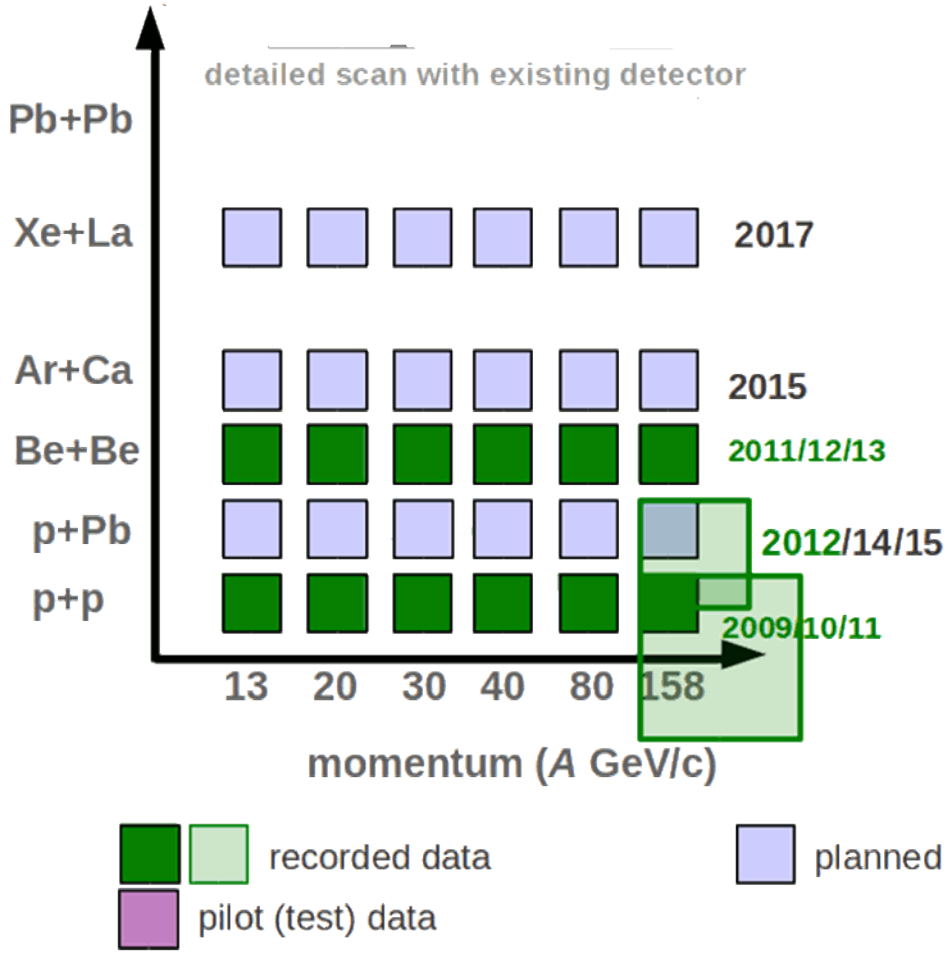


Detector layout and data taking program

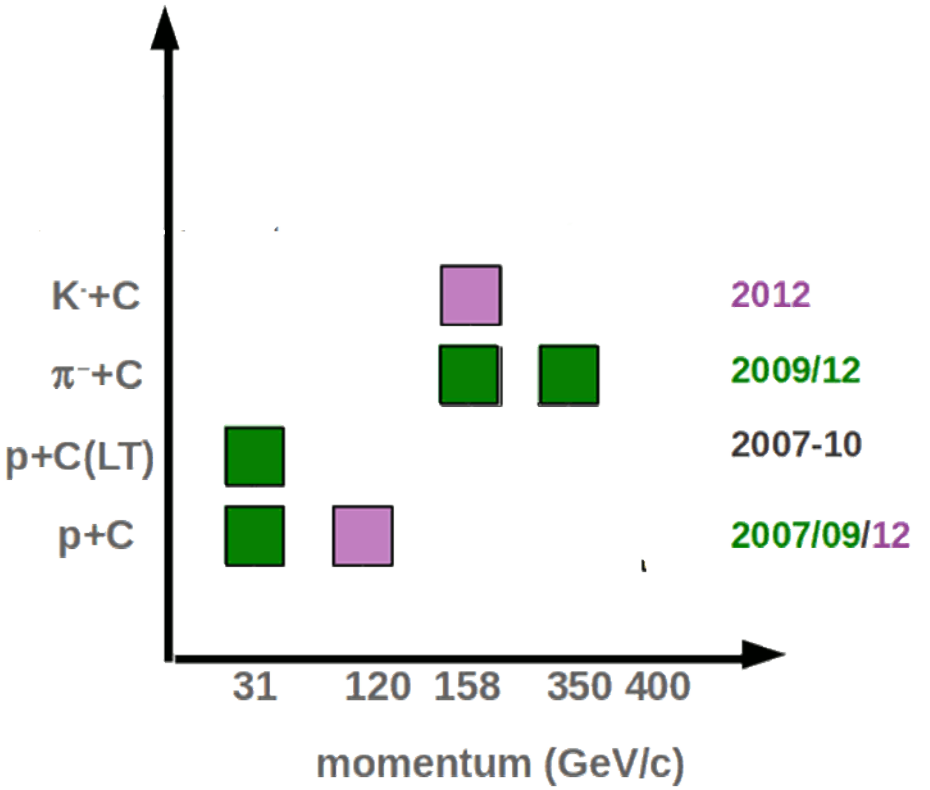
- NA61/SHINE is a fixed-target hadron spectrometer experiment at the CERN SPS.
- Its tracking system was inherited from former experiment NA49.
- Several upgrades were done, motivated by requirements of physics goals.
- Beamline upgrade was performed for fragmented ion beams (Be).



Status of the NA61 data taking within the ion program

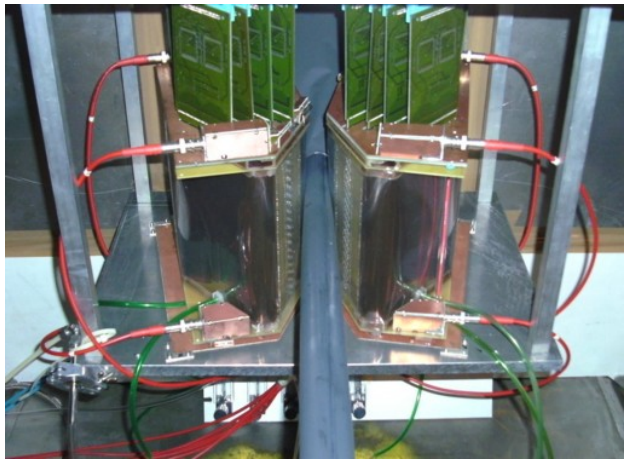


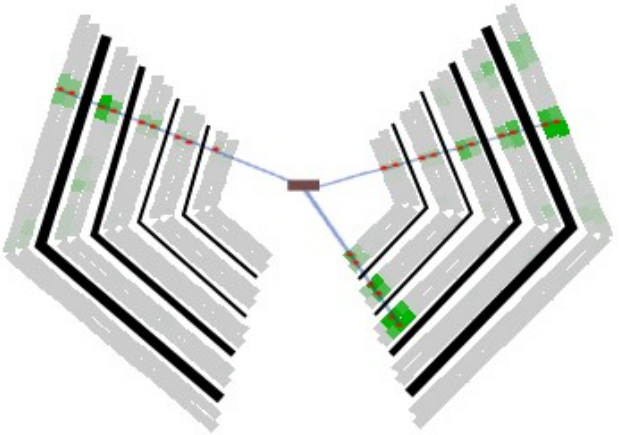
Status of the NA61 data taking within the neutrino and cosmic ray programs

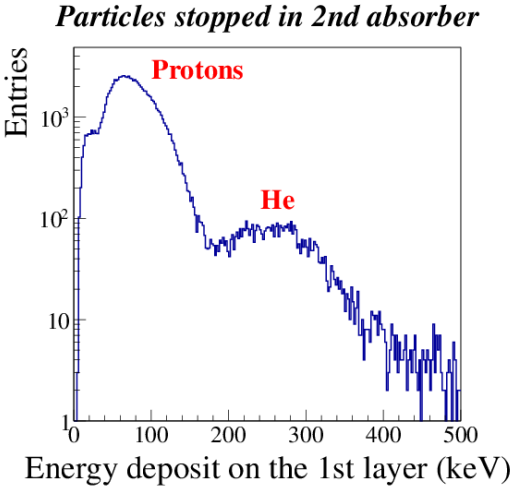


- Energy scan with p+p finished, large stat p+p data at 158 GeV/c was recorded.
- First half of the large stat p+Pb data at 158 GeV/c was recorded.
- Important milestone reached by finishing Be+Be energy scan – involved fragmented beam.

- Special detector (LMPD) was constructed for centrality determination in p+Pb:

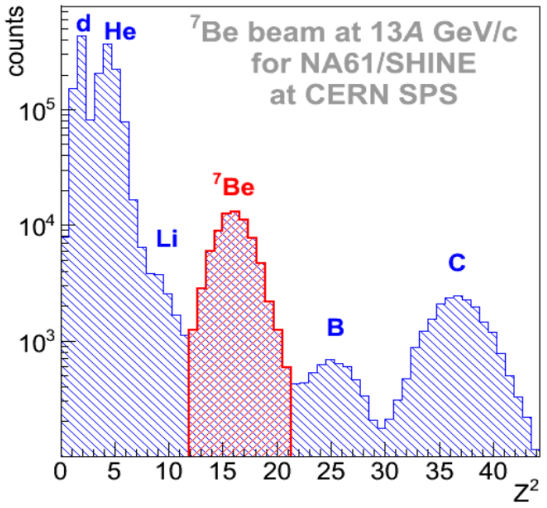


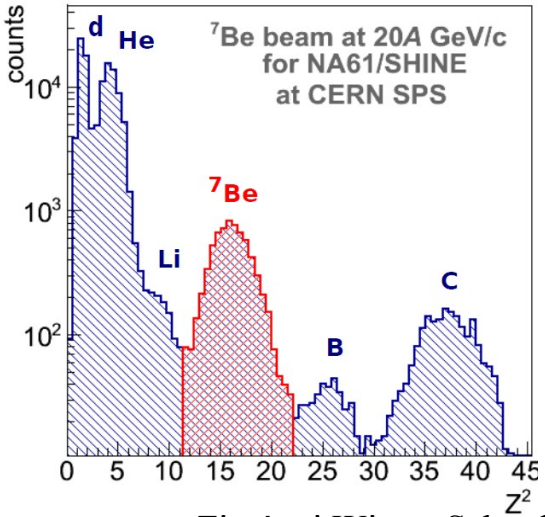


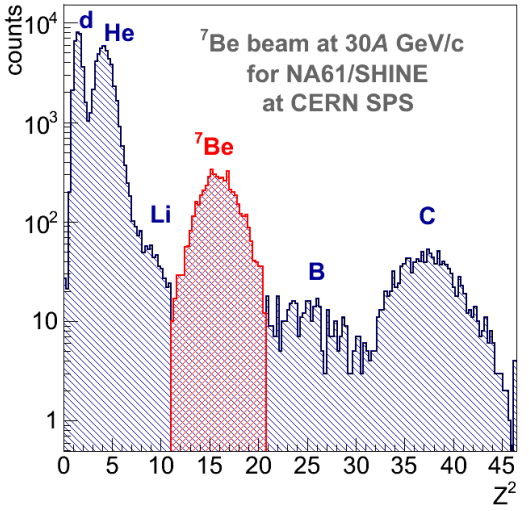


- Special detector (PSD) was used for centrality determination in A+A.
- Special beamline and beam detectors were constructed for Be (fragmented) beam:

  Fragmentation of Pb, fragment separator beamline, Cherenkov Z^2-identification

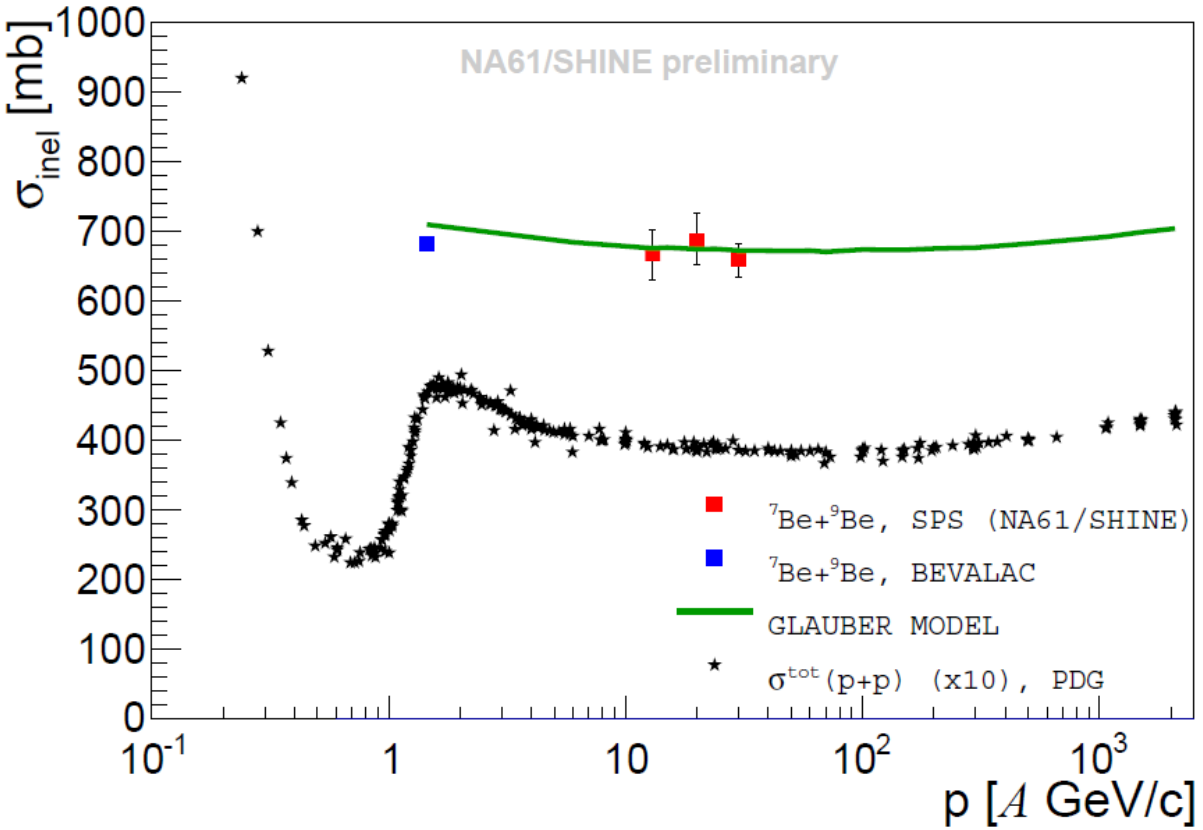






Recent physics results

Energy dep. of inelastic ^{7}Be+^{9}Be xsection (preliminary)



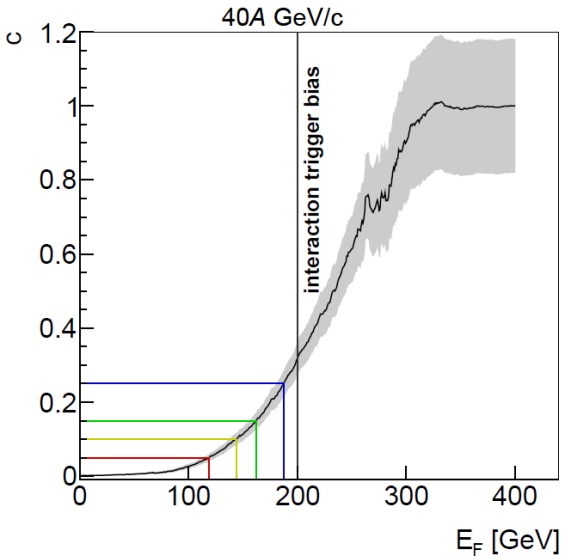
NA61 measurements together with existing 1*A* GeV/c measurement established energy dependence of the inelastic Be+Be cross section

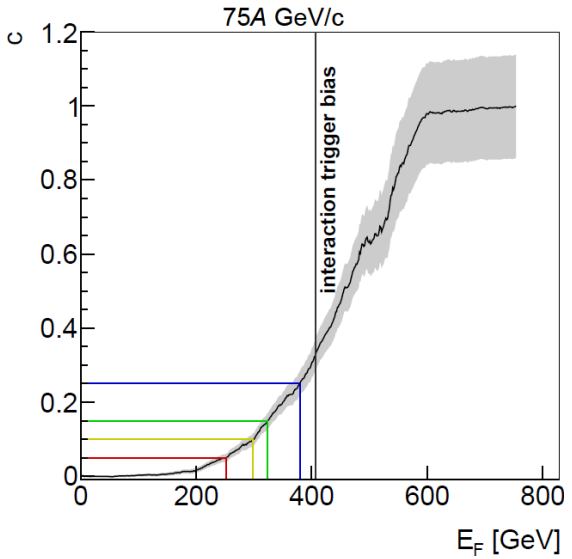
Phys. Rev. Lett. **55** (1985) 2676.
Comput.Phys.Commun. 180 (2009) 69.

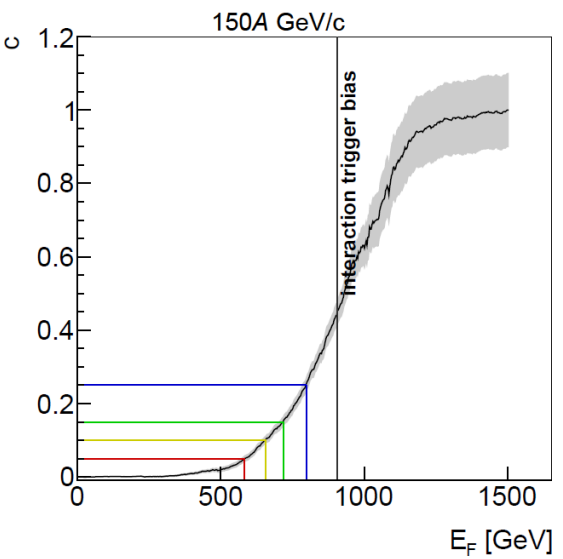
π^- spectra in $^7Be+^9Be$ (preliminary)

- Centrality was differentiated using forward spectator energy E_F measured by PSD.
- Four centrality classes used: 0-5%, 5-10%, 10-15%, 15-25%

$$c(E_F) = \frac{1}{P_{int}^{S4}} \int_0^{E_F} P_{int}(E'_F)\, dE'_F.$$







Centrality differentiated y – p_T spectra of π^- production in ^{7}Be+^{9}Be

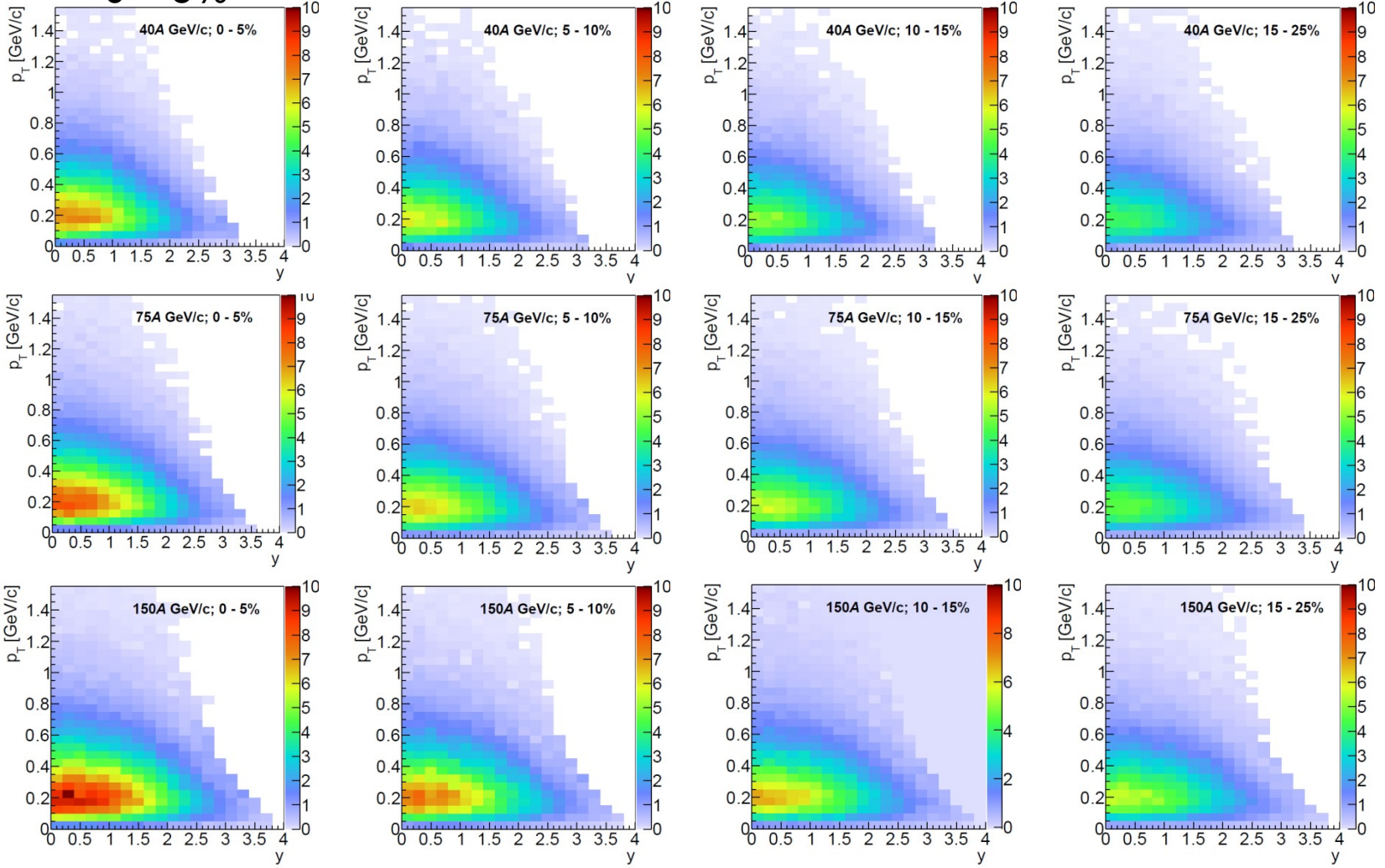
(h^- method)

– centrality –

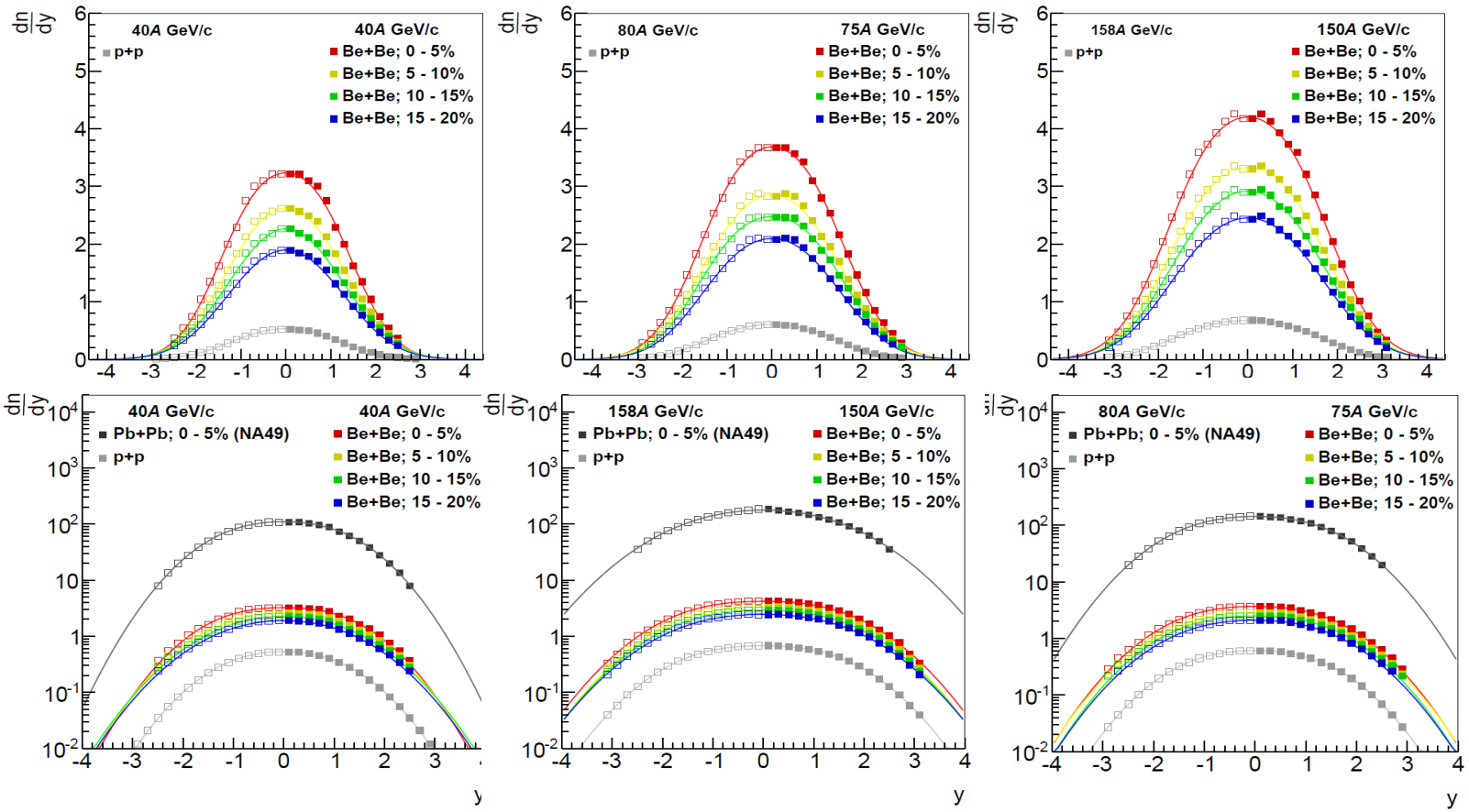
0 – 5%

15 – 25%

beam momentum / nucleon →

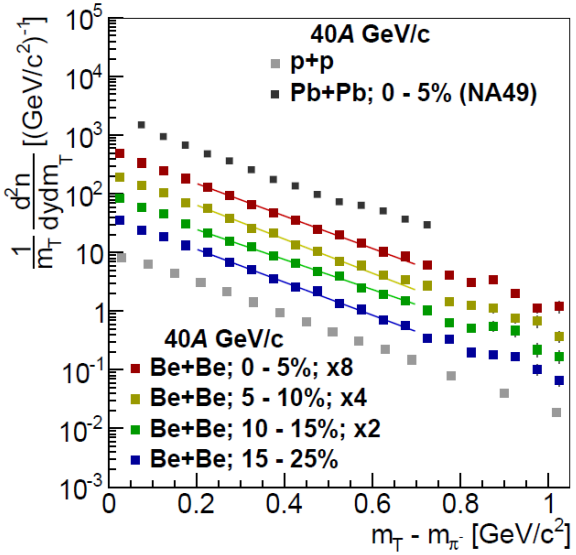


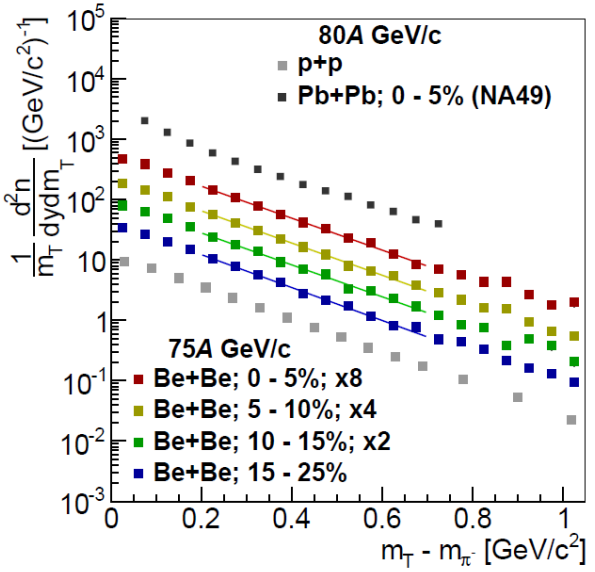
Integrated to p_T :

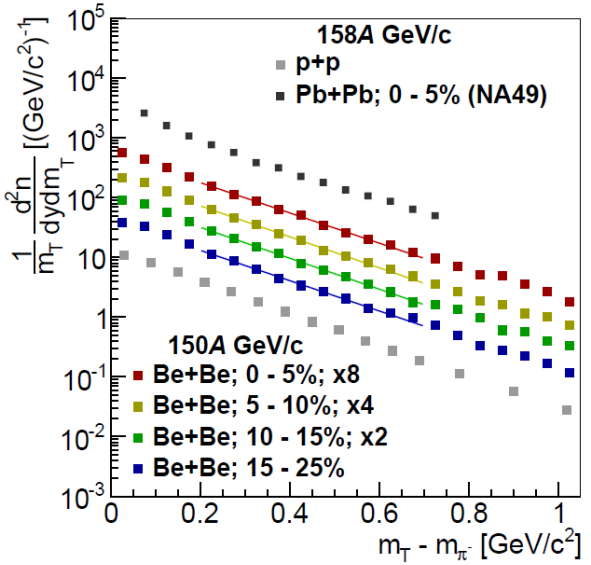


- Shown along with p+p and central Pb+Pb(NA49)
- Determination of number of wounded nucleons and correction for isospin effects in progress

At midrapidity(0.0 <= y <= 0.2) :



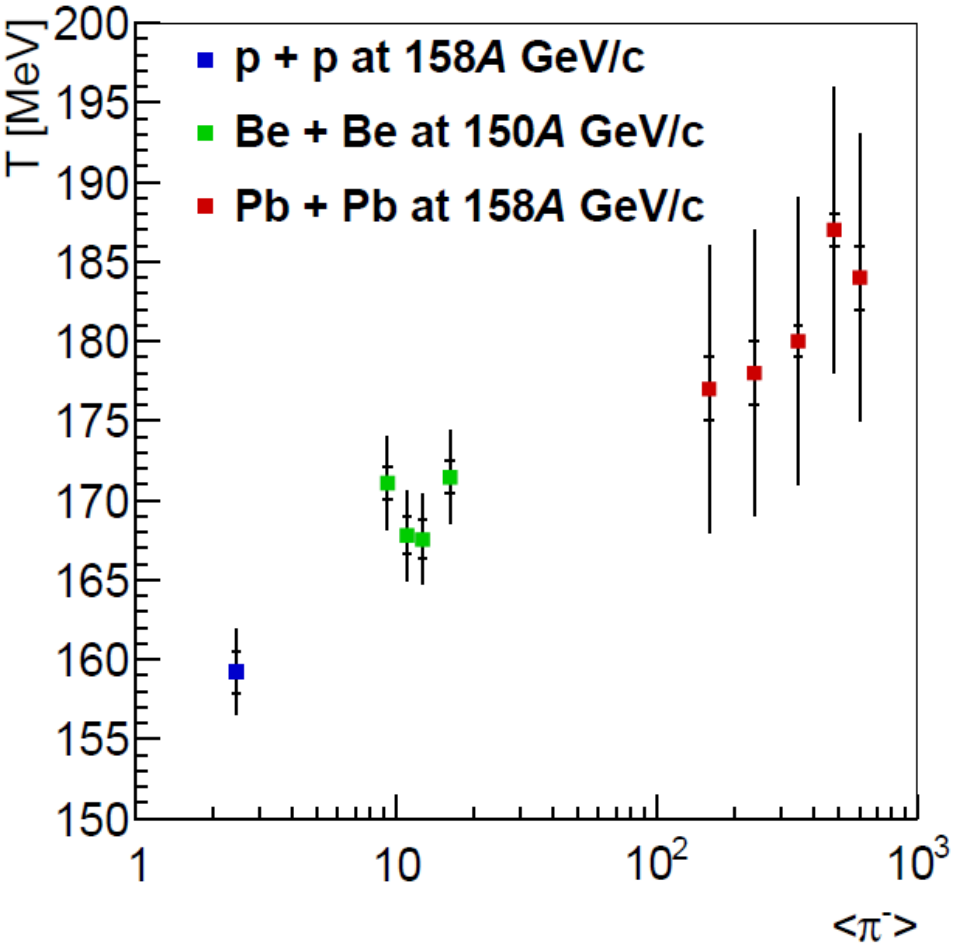




- Fitted inverse slope in 0.2 <= m_T <= 0.7 GeV/c^2

$$\frac{\mathrm{d}n}{\mathrm{d}m_\mathrm{T}} = A\, m_\mathrm{T}\, \exp\left(-\frac{m_\mathrm{T}}{T}\right)$$

Inverse slope parameter T of m_T spectra:



fitted in the range
0.2 < mT - mπ < 0.7 GeV/c2

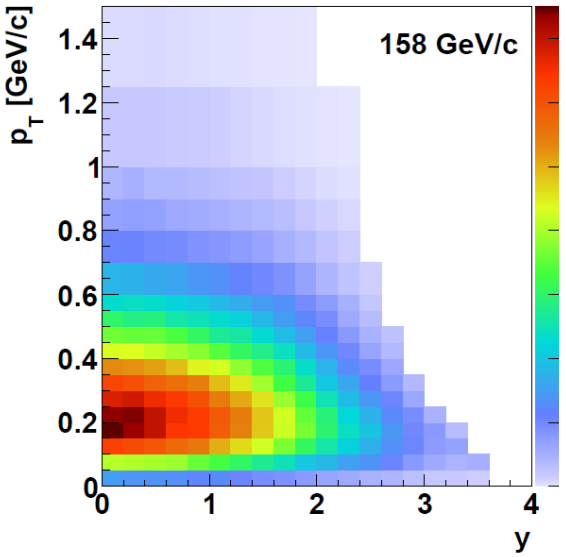
The T parameter is significantly larger in Be+Be collisions than in p+p interactions.

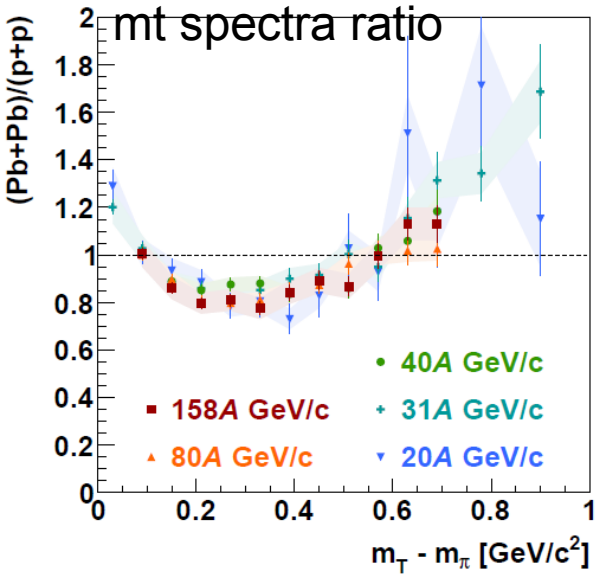
Evidence for transverse collective flow in Be+Be collisions

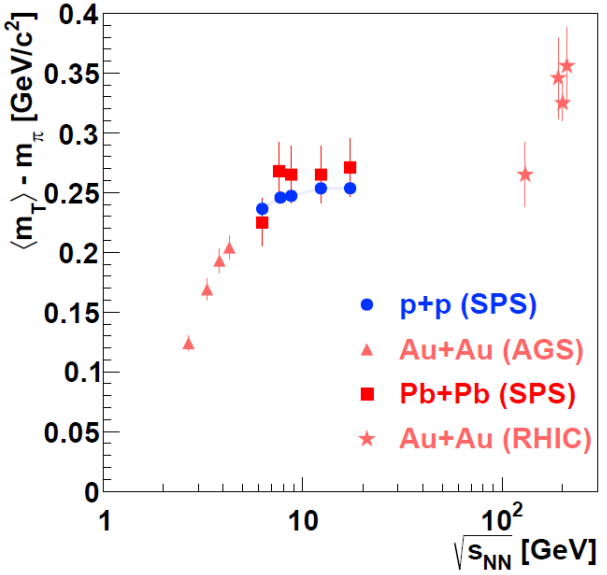
π^- spectra in p+p

- Important referenc data for ion measurements.

  (h^- method)







Spectra of $\pi-$ in p+p collisions at 20, 31, 40, 80, and 158 GeV/c

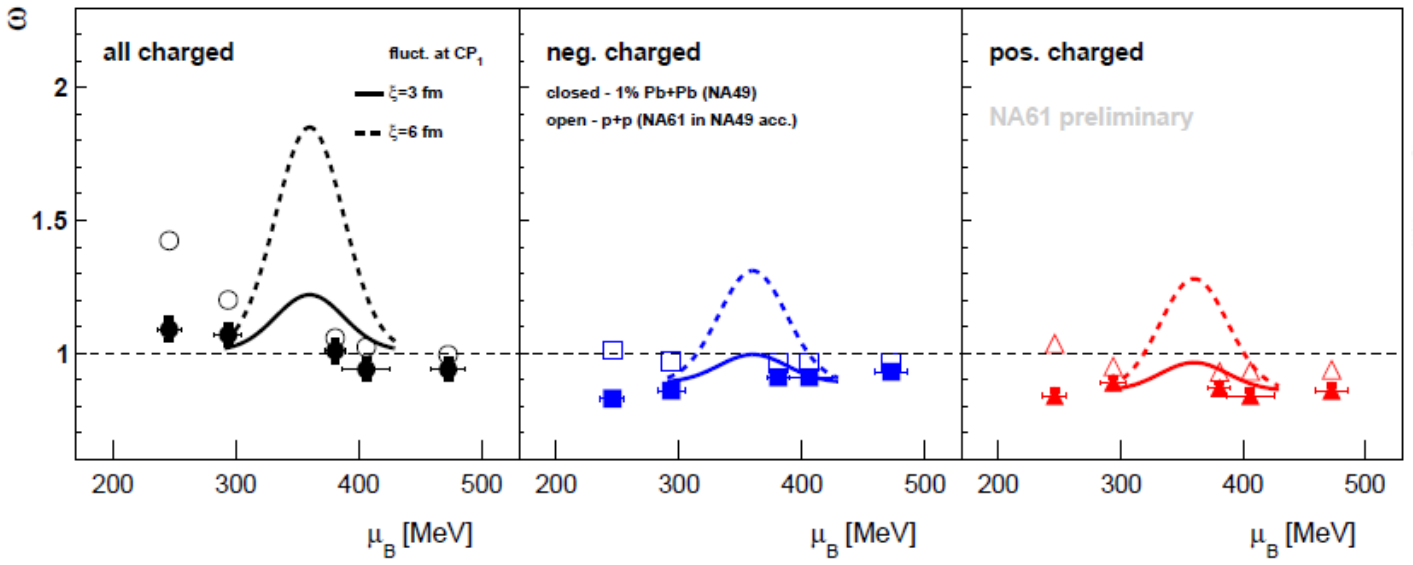
Different shape in p+p and central (7%) Pb+Pb, independent of beam energy

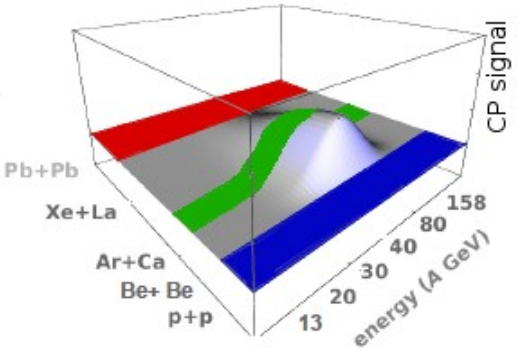
Mean transverse mass independent of system size

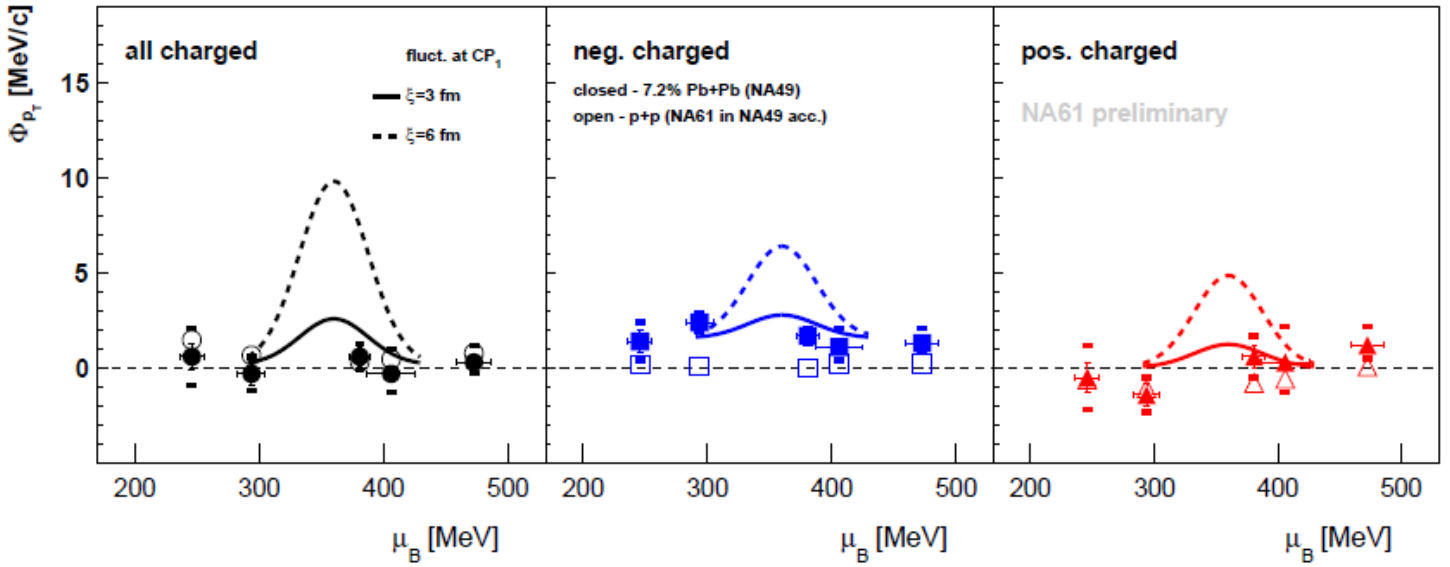
NA49 data: PRC77 (2008) 024903, PRC66 (2002) 054902

Multiplicity and p_T fluctuations in p+p

comparison with central Pb+Pb collisions (NA49)



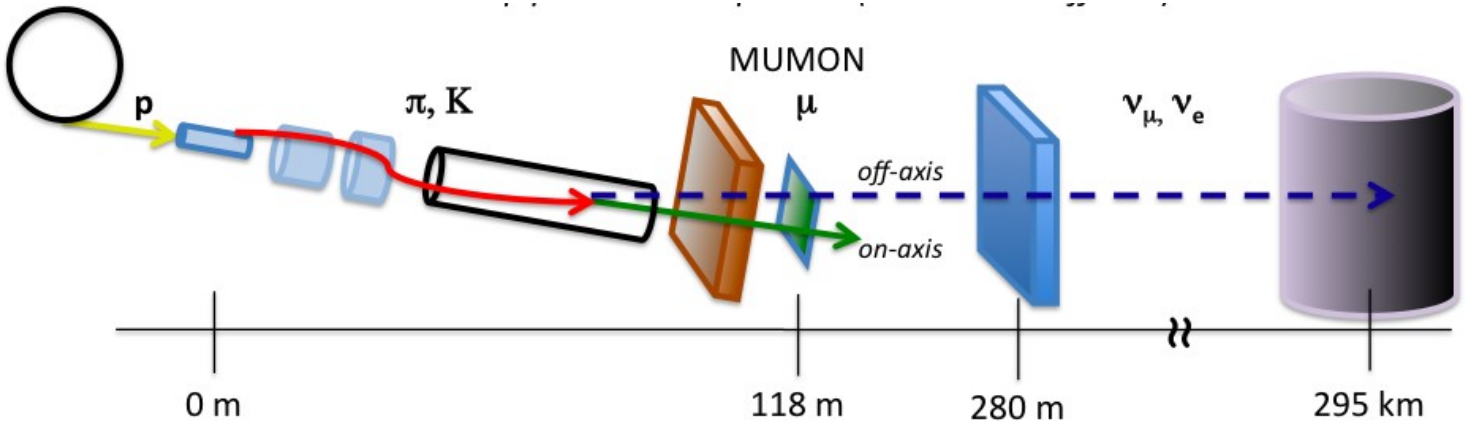




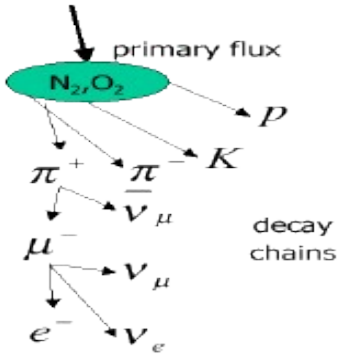
The p+p reference dependence of critical point signatures has been established.
Working on the results from Be+Be collisions waiting for Ar+Ca and Xe+La data.

Hadron production for neutrino & CR physics

Precision measurements of hadron production for the prediction of ν-fluxes at T2K

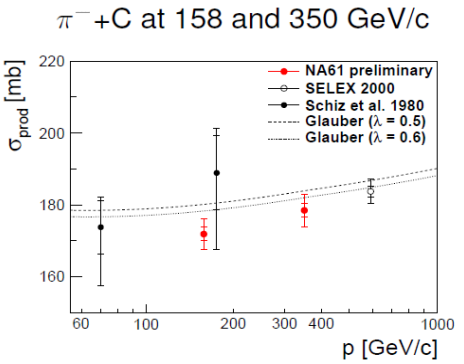


Systematic error estimate based on the NA61/SHINE results:
Phys.Rev. C85 (2012) 35210,
Phys.Rev. C84 (2011) 34604,
NIM A709 (2013) 68-71.



Measurements of Cosmic Rays with large area shower detectors suffer from large systematic errors from modeling of shower evolution.

These are mostly effected by hadron production in meson + air nucleus collisions.



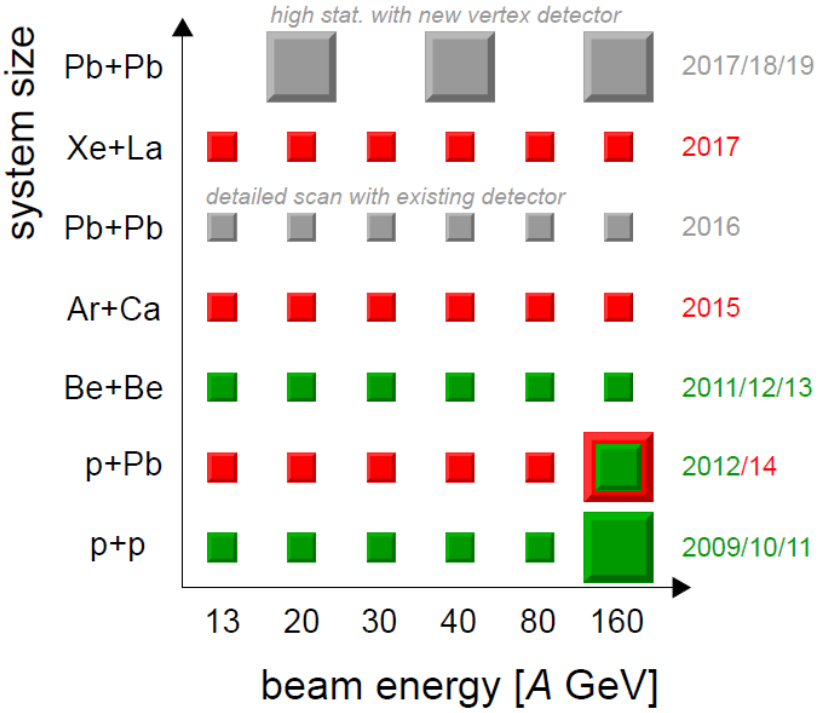
Plans and schedule

Approved plan:

- Data taking continues with finishing large stat p+Pb.
- The data sets Ar+Ca and Xe+La are special – need primary Ar and Xe beams.

Beam Primary	Beam Secondary	Target	Momentum (A GeV/c)	Year	Days	Physics
p			400			
	p	Pb	158	2014	30 days	high p_T
Ar		Ca	13, 19, 30, 40, 75, 150	2015	6×8 days	CP, OD
p			400			
	p	Pb	13, 19, 30, 40, 75, 150	2015	6×7 days	CP, OD
Xe		La	13, 19, 30, 40, 75, 150	2017	6×8 days	CP, OD

For ion physics:

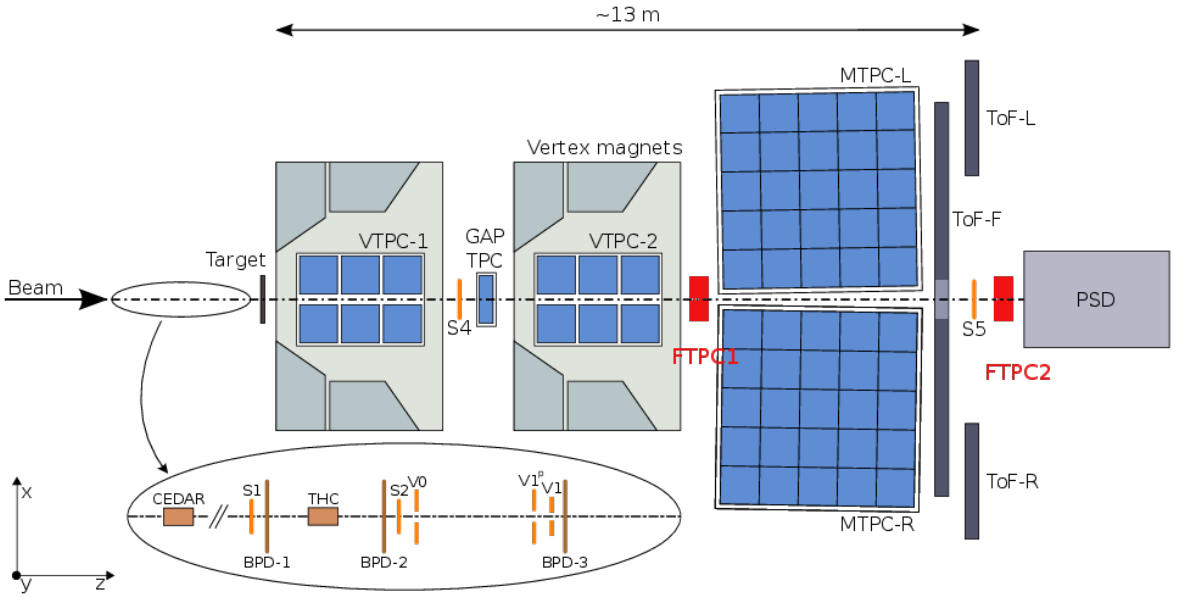


Proposed extension: Pb+Pb collisions

- Energy scan in 2016?
  - Complement NA49 results by high precision NA61 measurments.
  - Addendum will be prepared.
- High statistic runs with vertex detector in 2017-2019?
  - Open charm and multi-strange hyperon production,
  - Transverse momentum spectra of identified hadrons up to about 7 GeV/c
  - Addendum only after successful propotype tests in 2015

For neutrino physics:

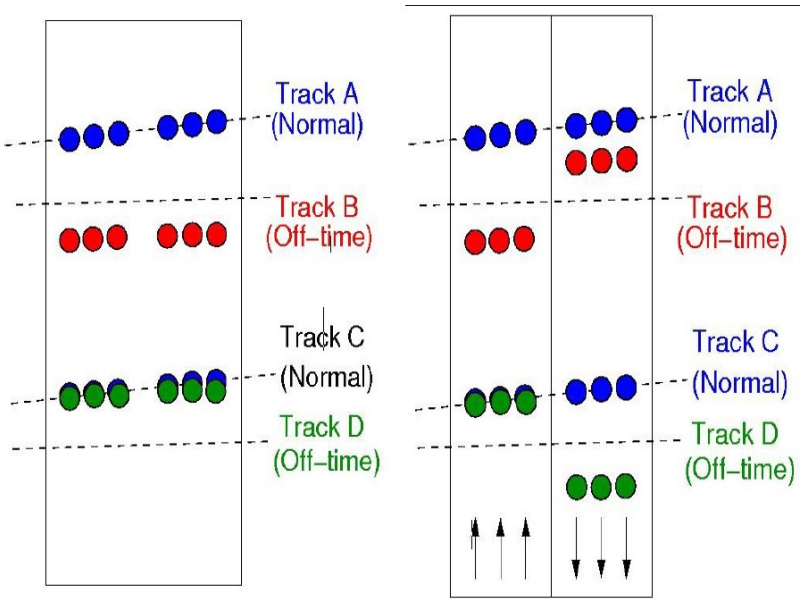
- p+C dataset at 120 GeV/c was requested by Fermilab neutrino community
  - Possible upgrade by forward TPCs (with cooperation of Colorado Uni. And Wigner RCP)



- Forward TPC motivated by neutrino beam physics

- Have to deal with larger track density and offtime particles => idea of Tandem-TPC with opposite drift fields

  (cooperation of Colorado Uni. And Wigner RCP)



Summary

- Completed energy scan with p+p and large stat p+p.
- Completed energy scan with Be+Be (fragmented ion beam).
- Half of large stat p+Pb recorded.
- Inelastic cross sections for Be+Be at 13 to 30*A* GeV/c.
- Pion spectra for Be+Be at 40 to 150*A* GeV/c.
- Final and prelim. spectra in p+p at 20 to 158 GeV/c.
- Final and prelim. spectra in p+C at 31 GeV/c for neutrino phys.
- Highest priority is to proceed with Ar and Xe beam data.
- Possible extension of program with open charm measurements and specific data for neutrino beam physics for Fermilab.