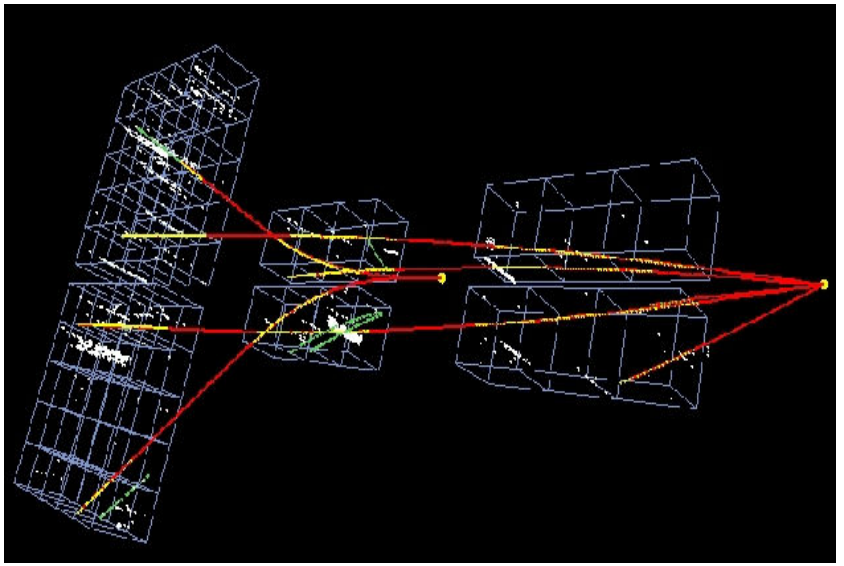
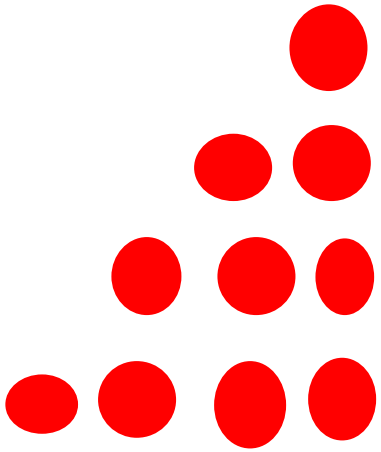
NA61/SHINE: Status and Data taking with ion beams

(SHINE – SPS Heavy Ion and Neutrino Experiment)



Proposal: *CERN-SPSC-2006-034, SPSC-P-330 (November 3, 2006)*
LoI: *CERN-SPSC-2006-001, SPSC-I-235 (January 6, 2006)*
EoI: *CERN-SPSC-2003-031, SPSC-EOI-001 (November 21, 2003)*

M. Gazdzicki, Frankfurt, Kielce
for the NA61 Collaboration



Fundamentals

Preliminary results from the 2007 pilot run

2009 physics run

Revised data taking schedule with ion beams

Addendum 5 to the proposal P300,
CERN-SPSC-2009-031 ; SPSC-P-330-ADD-5

Physics goals (I):

Physics of strongly interacting matter

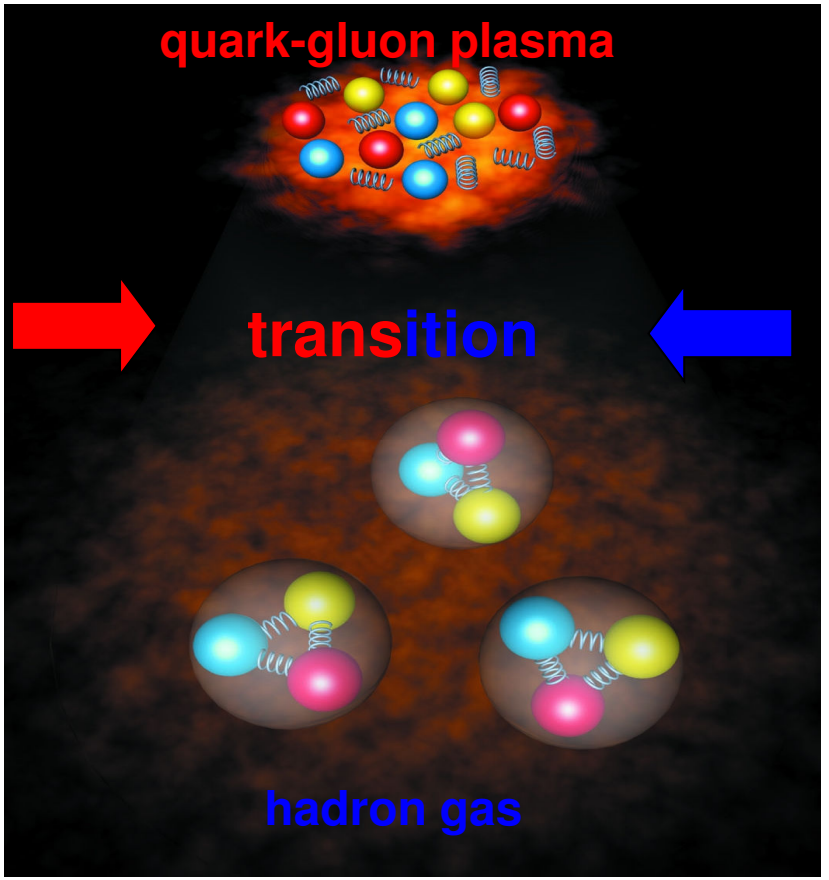
Discovery potential:

Search for the critical point of strongly interacting matter

Precision measurements:

Study the properties of the onset of deconfinement in nucleus-nucleus collisions

Measure hadron production at high transverse momenta in p+p and p+Pb collisions as reference for Pb+Pb results



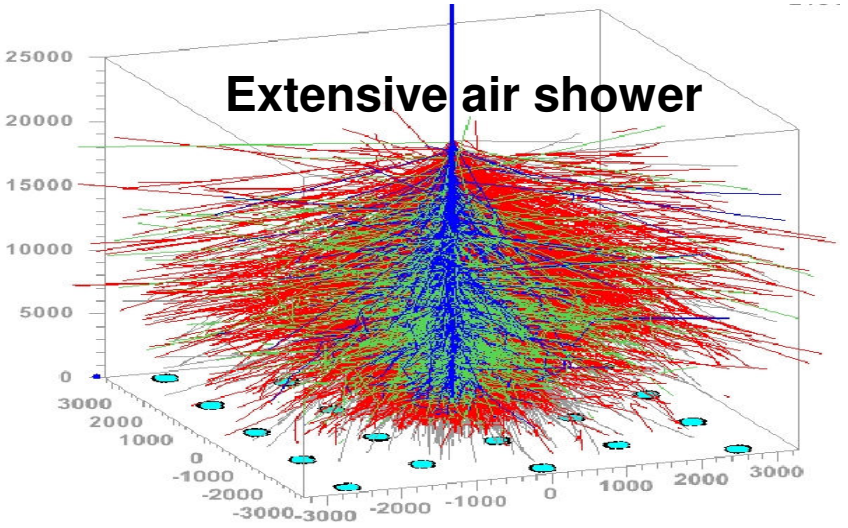
Physics goals (II):

Data for neutrino and cosmic ray experiments

Precision measurements:

Measure hadron production in p+C interactions needed for T2K and cosmic-ray, Pierre Auger Observatory and KASCADE, experiments

Measure hadron production in the T2K target needed for the T2K (neutrino) physics

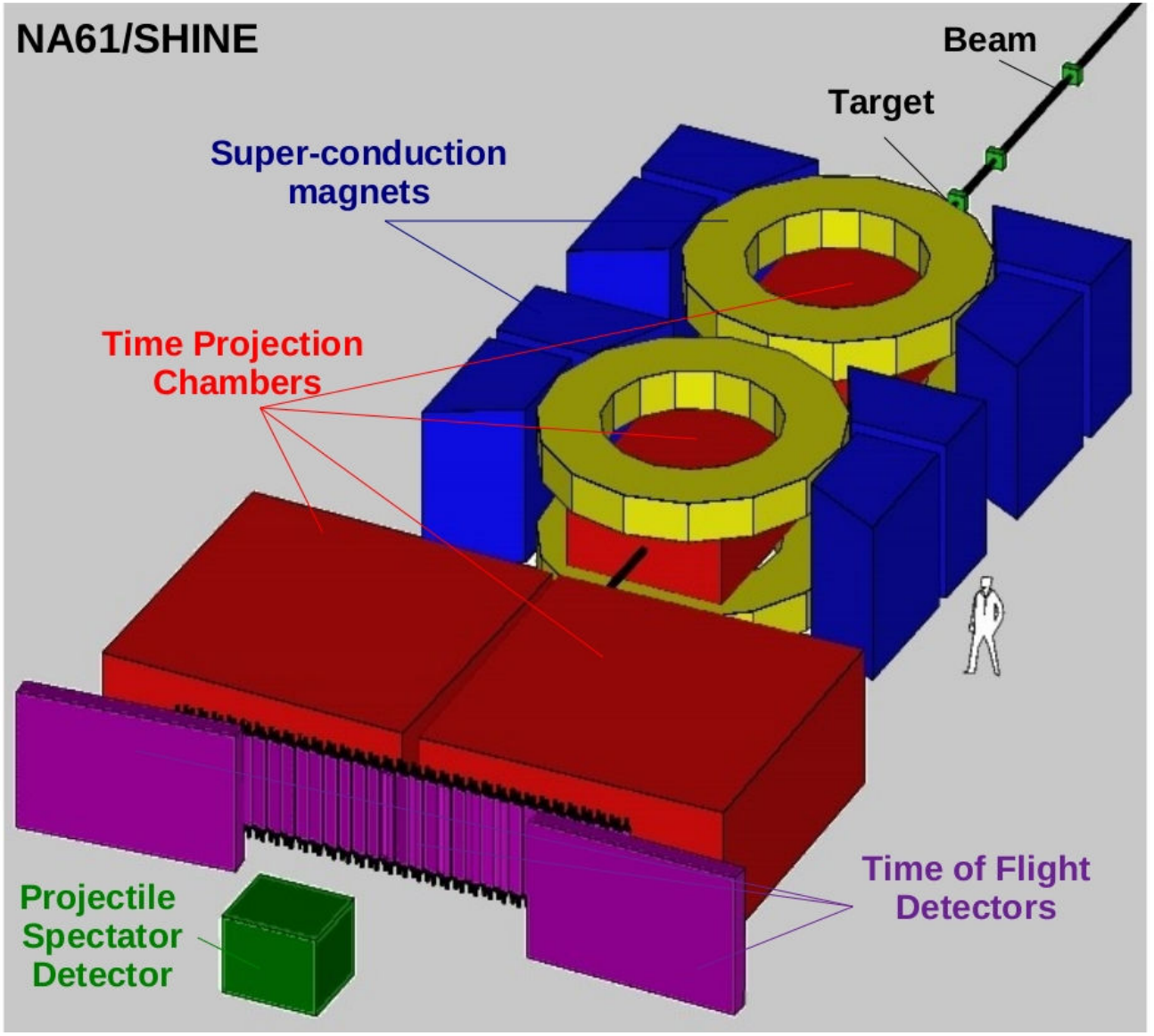


The NA61/SHINE Collaboration:

122 physicists from 24 institutes and 13 countries:

University of Athens, Athens, Greece
University of Bergen, Bergen, Norway
University of Bern, Bern, Switzerland
KFKI IPNP, Budapest, Hungary
Cape Town University, Cape Town, South Africa
Jagiellonian University, Cracow, Poland
Joint Institute for Nuclear Research, Dubna, Russia
Fachhochschule Frankfurt, Frankfurt, Germany
University of Frankfurt, Frankfurt, Germany
University of Geneva, Geneva, Switzerland
Forschungszentrum Karlsruhe, Karlsruhe, Germany
Institute of Physics, University of Silesia, Katowice, Poland
Jan Kochanowski Univeristy, Kielce, Poland
Institute for Nuclear Research, Moscow, Russia
LPNHE, Universites de Paris VI et VII, Paris, France
Faculty of Physics, University of Sofia, Sofia, Bulgaria
St. Petersburg State University, St. Petersburg, Russia
State University of New York, Stony Brook, USA
KEK, Tsukuba, Japan
Soltan Institute for Nuclear Studies, Warsaw, Poland
Warsaw University of Technology, Warsaw, Poland
University of Warsaw, Warsaw, Poland
Rudjer Boskovic Institute, Zagreb, Croatia
ETH Zurich, Zurich, Switzerland

Detector



NA49 facility +

TPC read-out (x10)
ToF (x2)
PSD (x10)
Beam pipe (x10)

NA49: Nucl. Instrum. Meth. A430, 210 (1999)

NA61 upgrades: CERN-SPSC-2006-034, SPSC-P-330

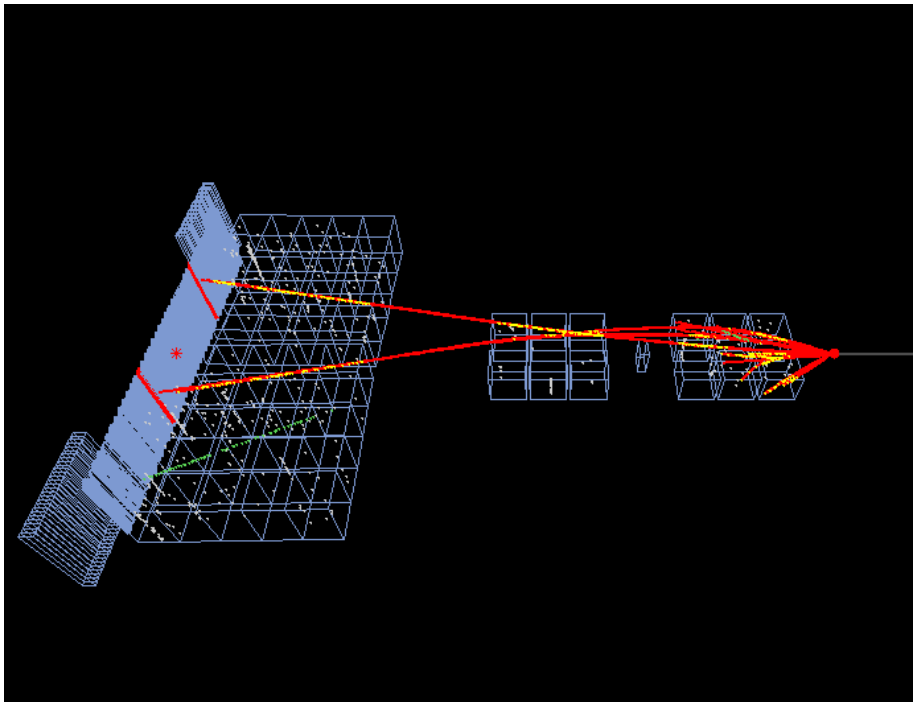
Preliminary results from the 2007 pilot run

Aims of the first NA61 run in October 2007:

- set up and test the NA61 apparatus and the detector prototypes,

- take pilot physics data for T2K with 31 GeV/c protons:

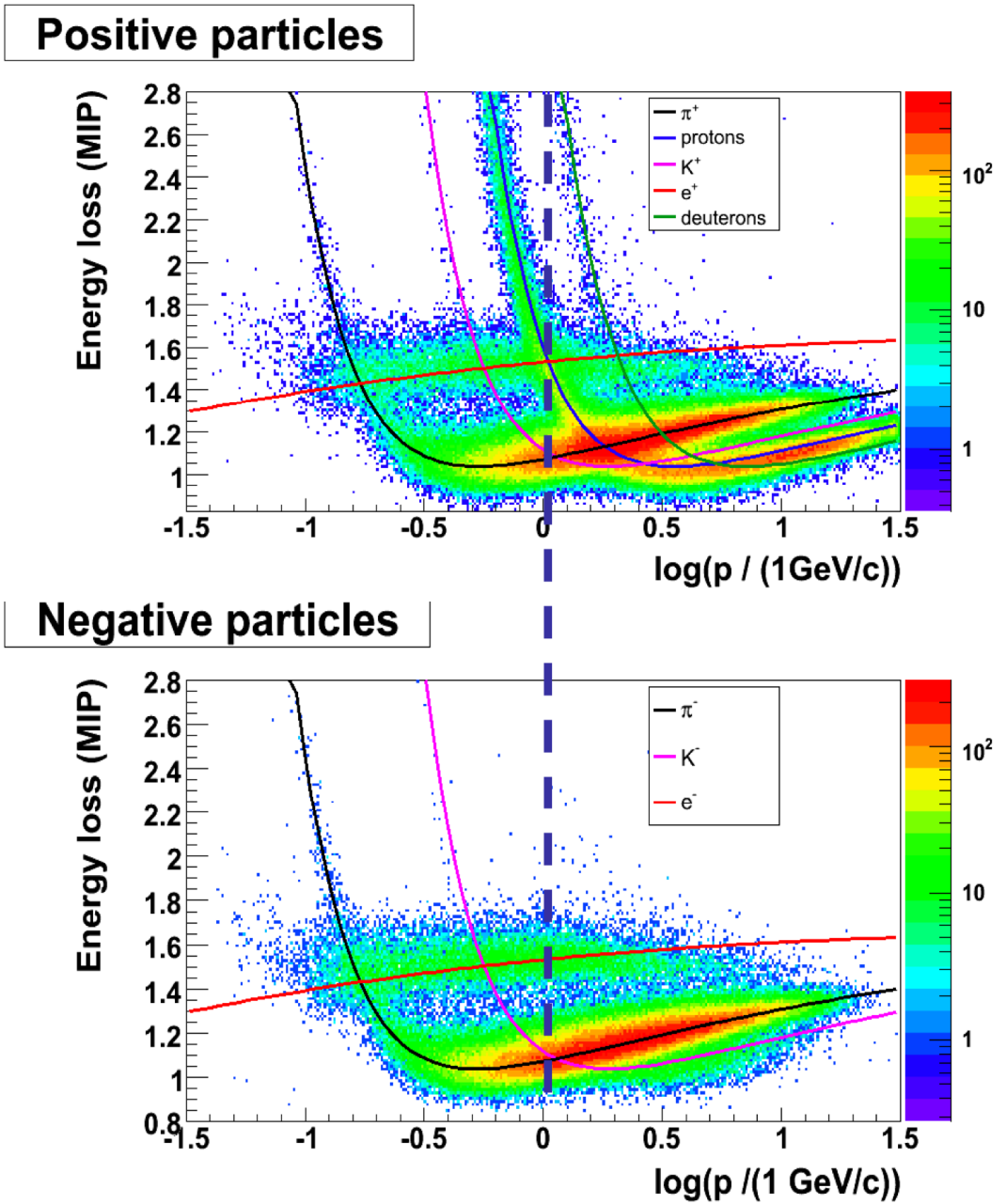
p+C at 31 GeV/c (660k events),
p+(T2K Replica Target) at 31 GeV/c (230k events)



Particle identification: dE/dx measurements

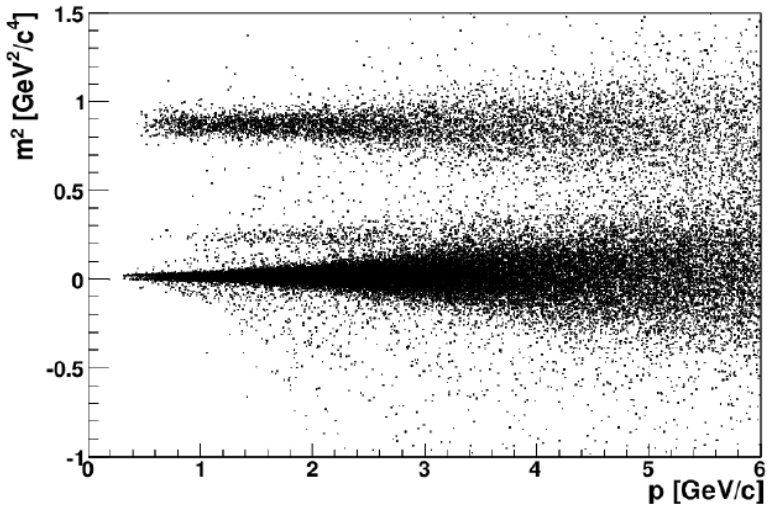
$\sigma(dE/dx)/\langle dE/dx\rangle \simeq 4\%$

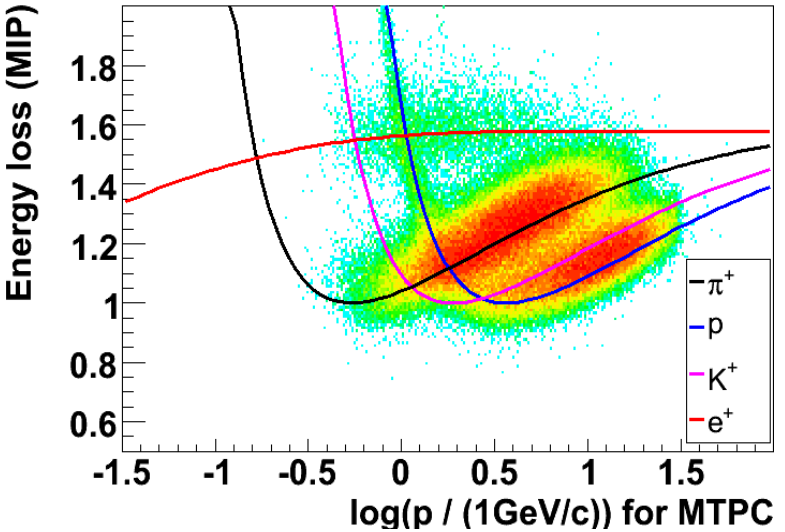
analysis in $1/\beta^2$ and relativistic rise regions



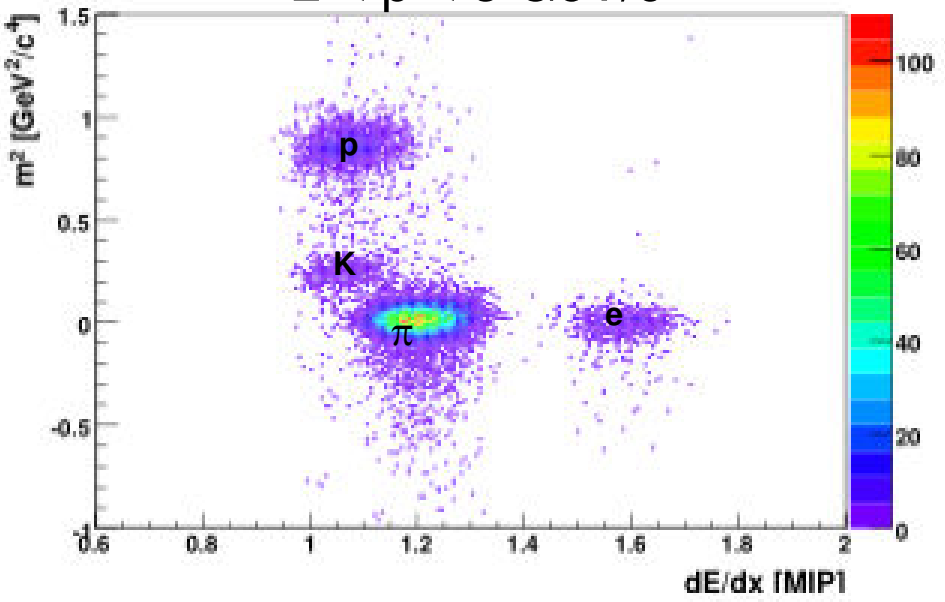
Particle identification: combined dE/dx and *tof*

σ(*tof*) ≈ 120 ps



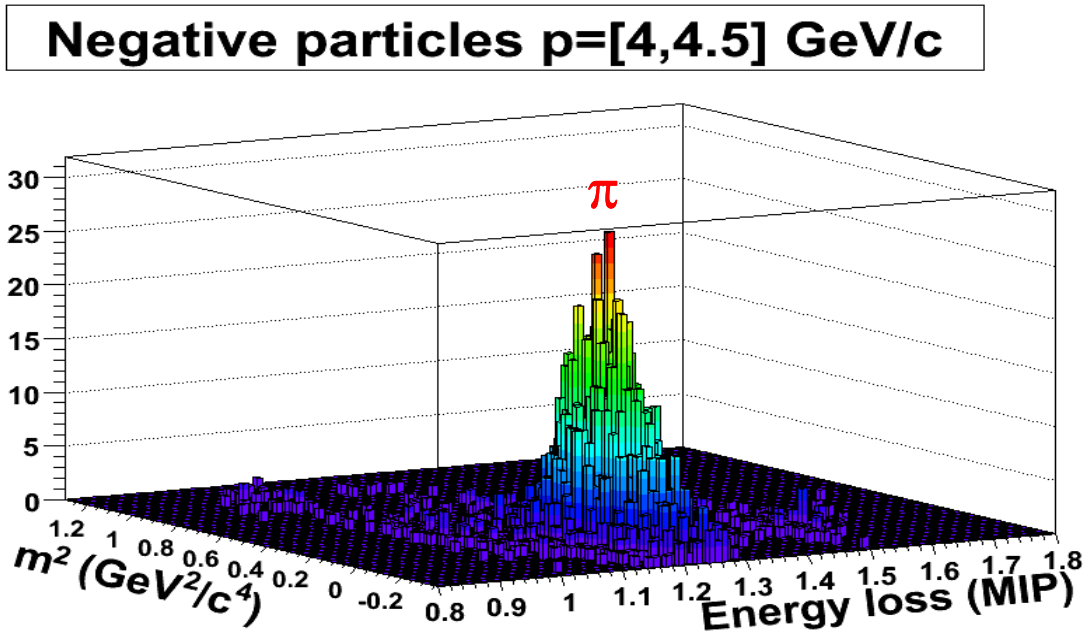


2 < p < 3 GeV/c



Murphy, Abgrall

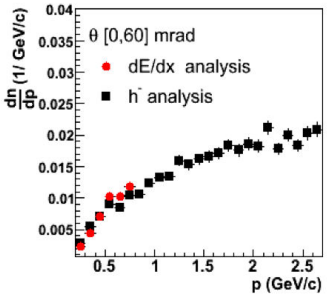
Particle identification: h- analysis

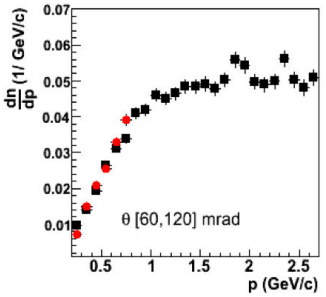


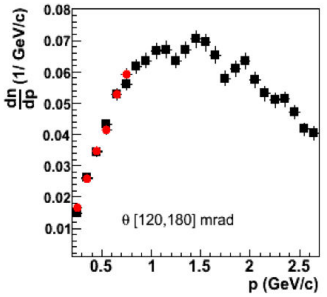
Majority of all negatively charged particles are pions

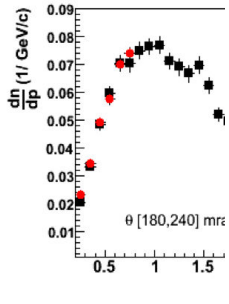
Pion spectra can be obtained by correcting for a non-pion contamination

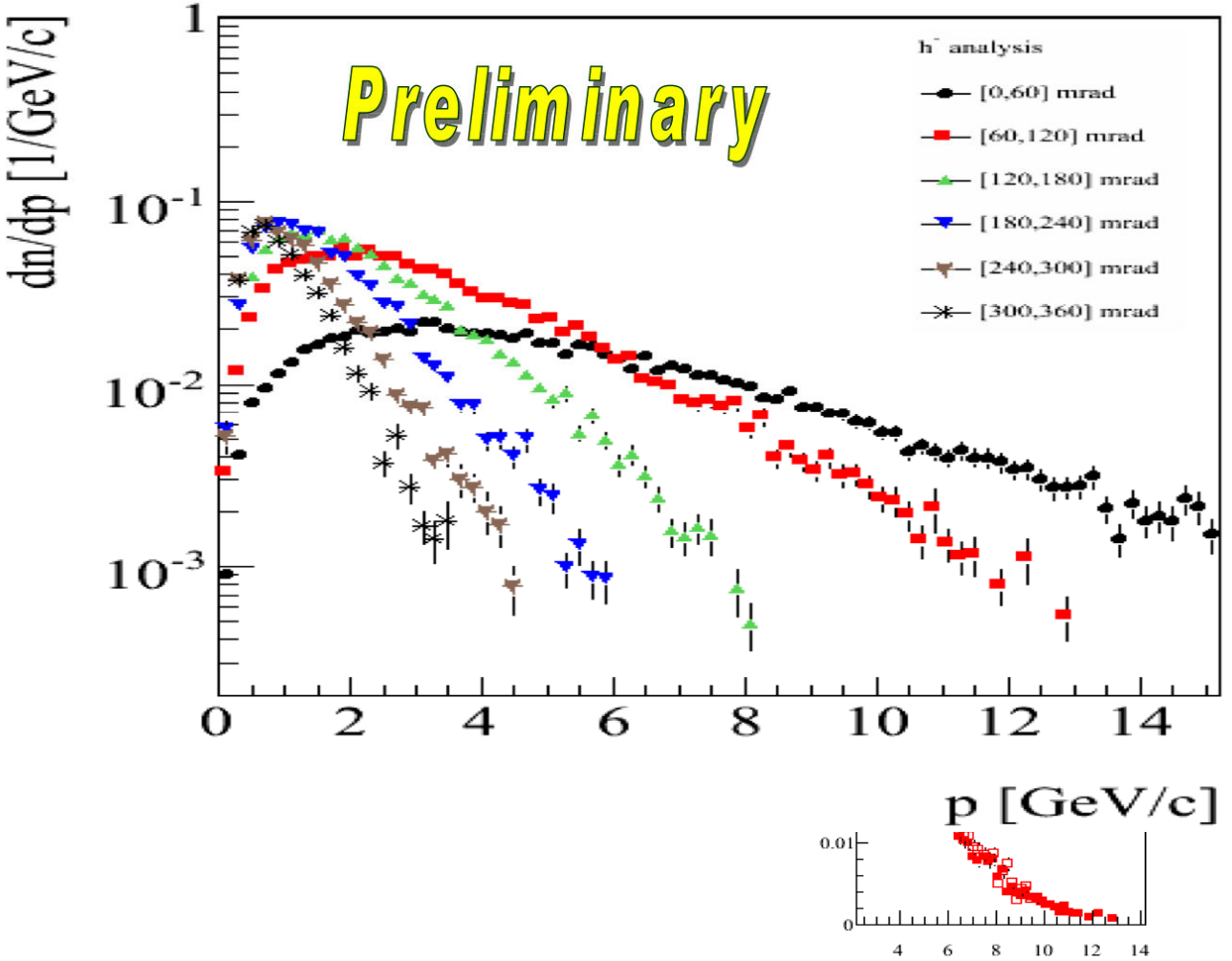
Preliminary pion spectra

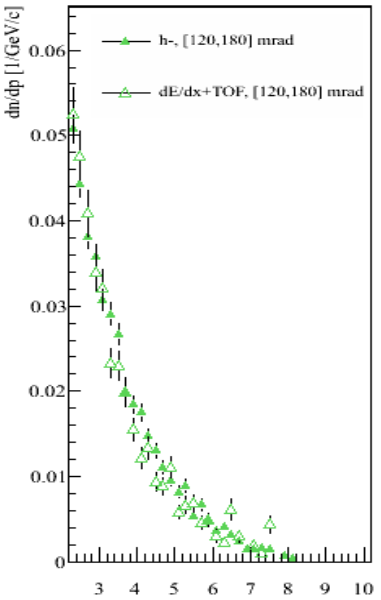












2009 physics run

Data taking period: July 26 – November 16

Aim: high statistics data for:

- T2K: p+C and p+(T2K RT) at 31 GeV/c
- cosmic-ray: π+C at 158 and 350 GeV/c
- CP, OD: p+p at 10-158 GeV/c

Registered in 2009:

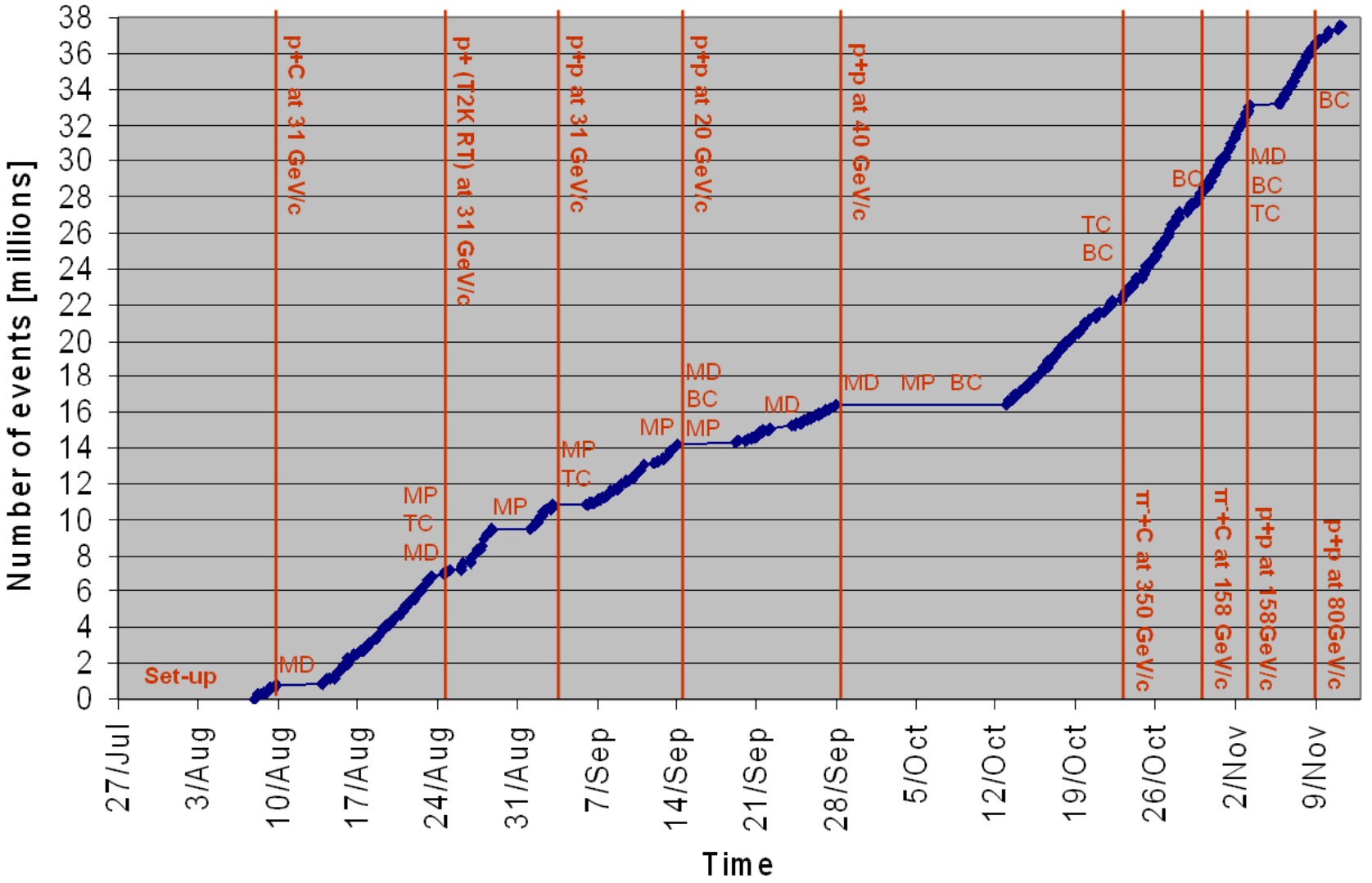
p+C at 31 GeV/c
p+(T2K RT) at 31 GeV/c

pion+C at 158 GeV/c
pion+C at 350 GeV/c

p+p at 20 GeV/c
p+p at 31 GeV/c
p+p at 40 GeV/c
p+p at 80 GeV/c
p+p at 158 GeV/c

p+p at 10 GeV/c were not registered due to insufficient beam quality

2009 run history



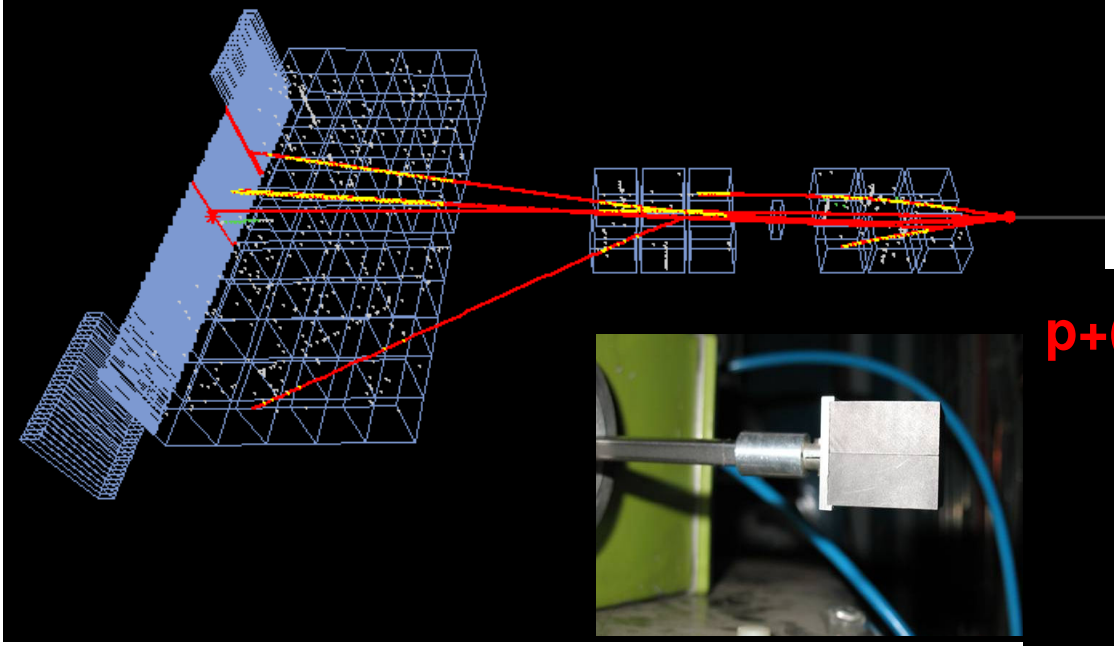
MD – Machine development
MP - Machine problems
TC - Target Change
BC - Beam Change

Many thanks to CERN machine as well as beam line operation and maintenance teams

2009 run: neutrinos

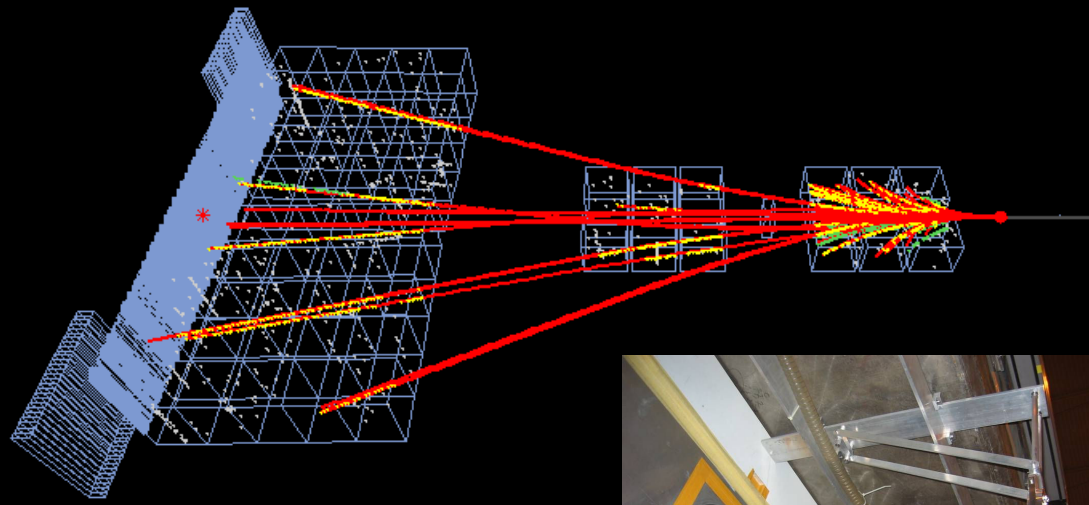
p+C at 31 GeV/c

6M events



p+(T2K replica target) at 31 GeV/c

4M events

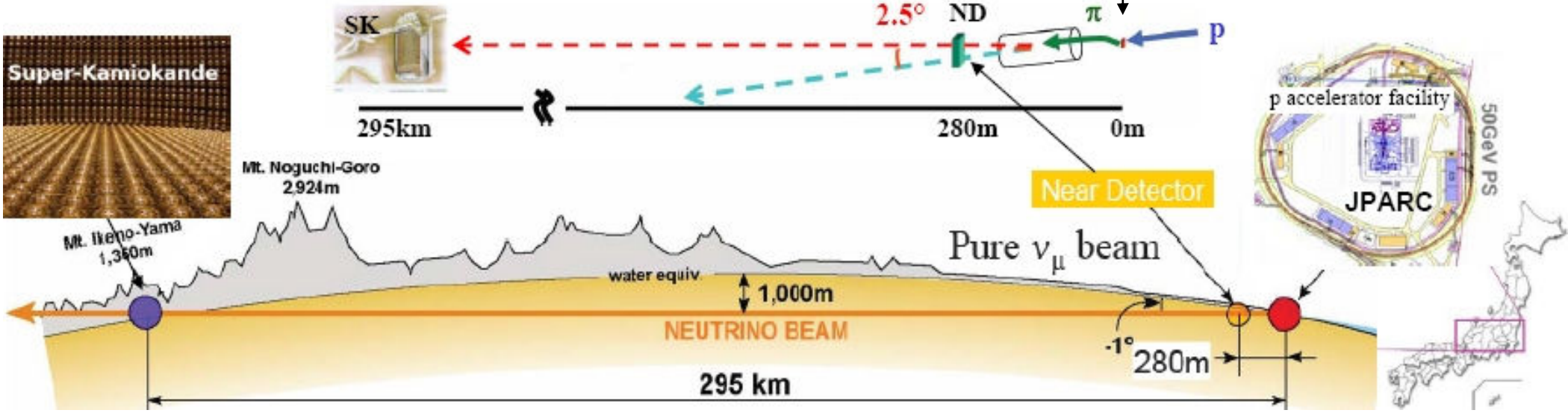


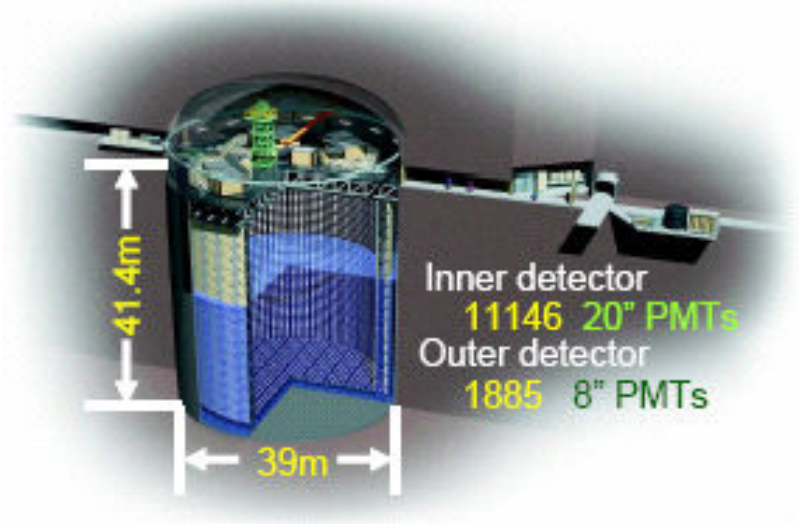
Measuring neutrino oscillations

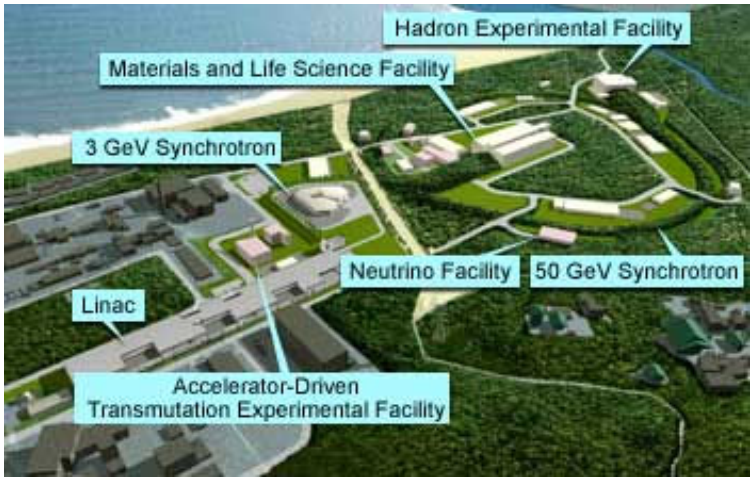
T2K

Measures initial neutrino flux

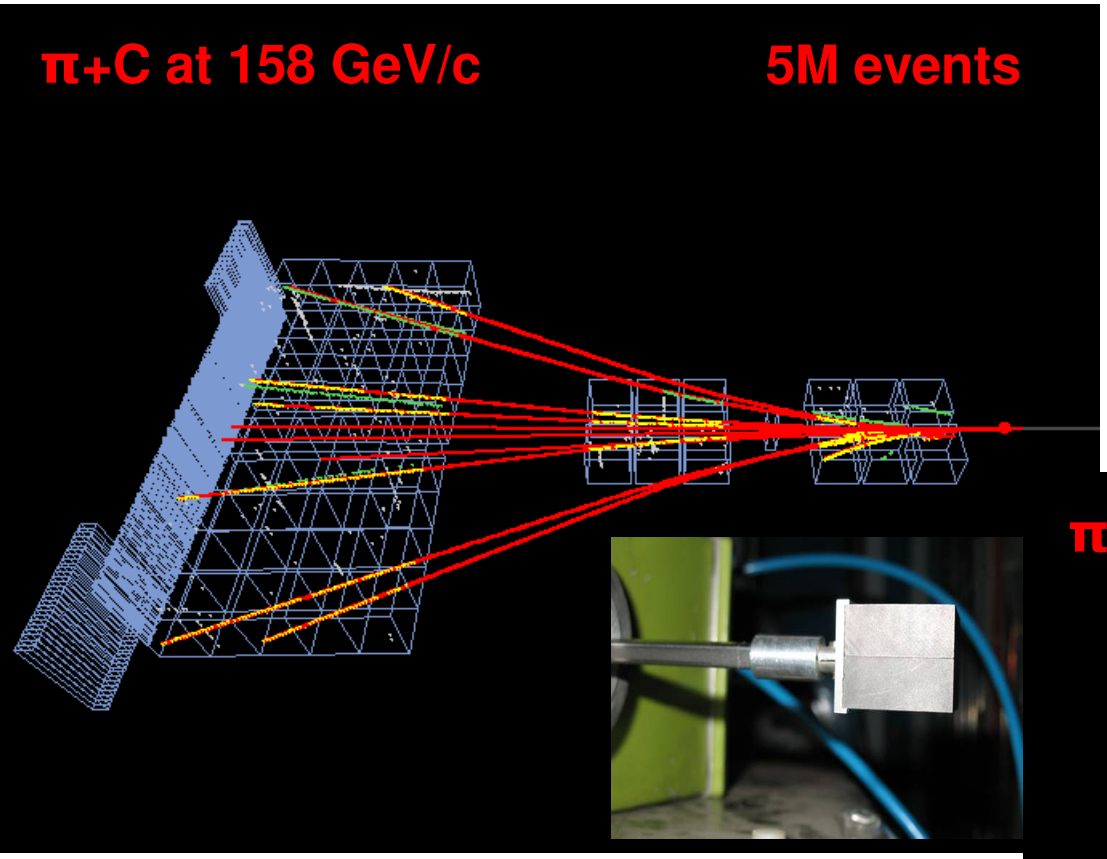
Measures initial neutrino flux

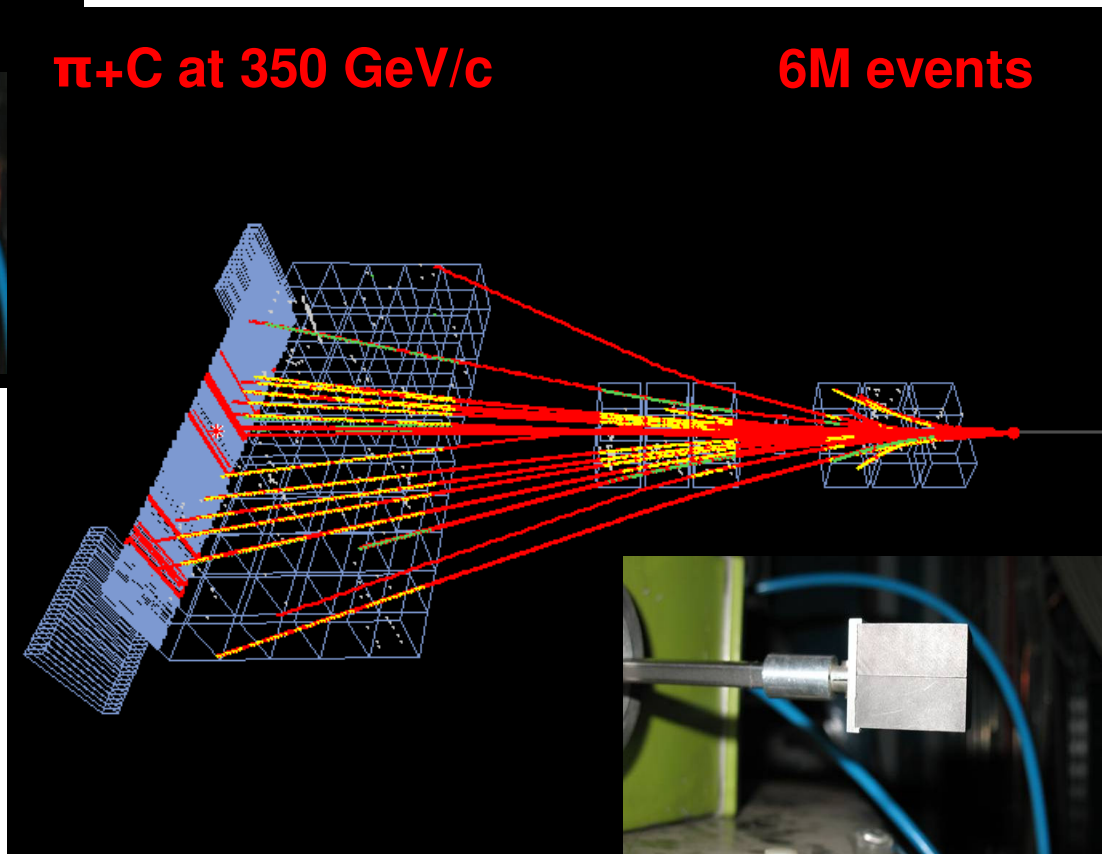






2009 run: cosmic-rays





Measuring cosmic-ray composition

p? | Fe?

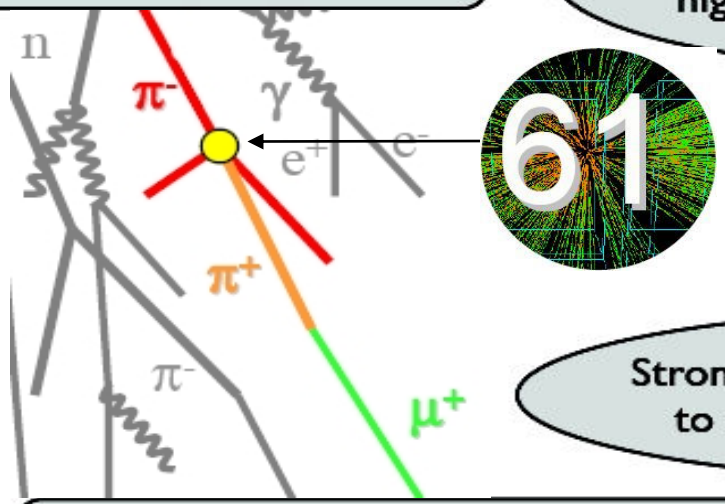
Cosmic ray composition: of central importance for understanding sources, knee, ankle, ...

Modern detector installations: high-statistics/quality data

Indirect measurement (extensive air showers): simulations needed

Strong model dependence: due mainly to simulation of muon production

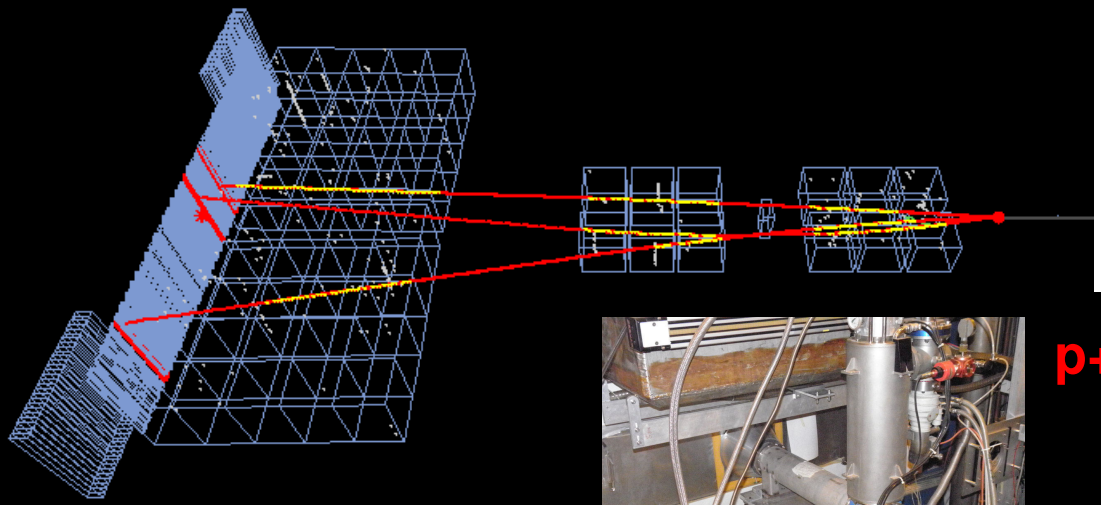
Muon production related to hadronic interactions at fixed-target energies



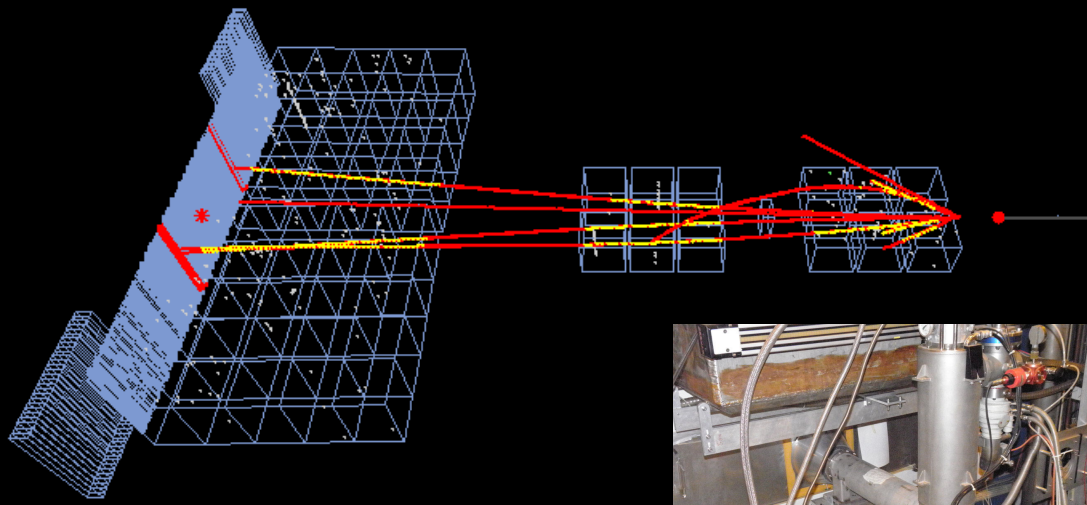
Pierre Auger Observatory

2009 run: strongly interacting matter (I)

p+p at 20 GeV/c **2M events**

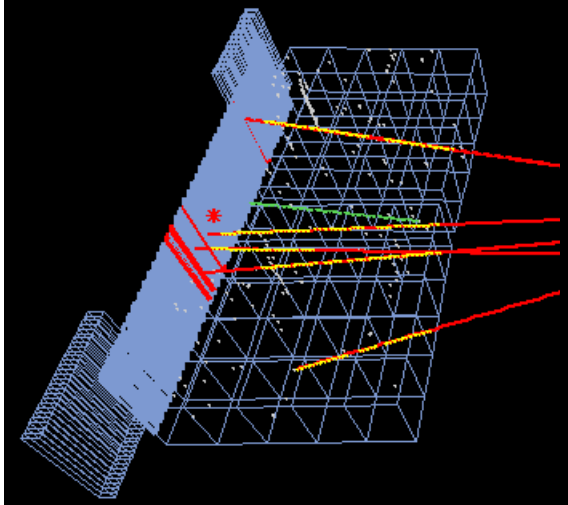


p+p at 31 GeV/c **3M events**

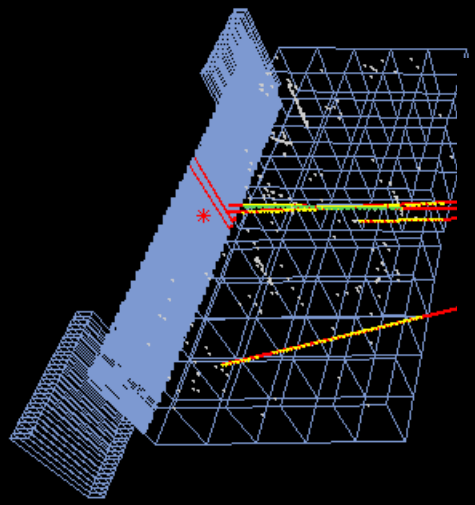


2009 run: strongly interacting matter (II)

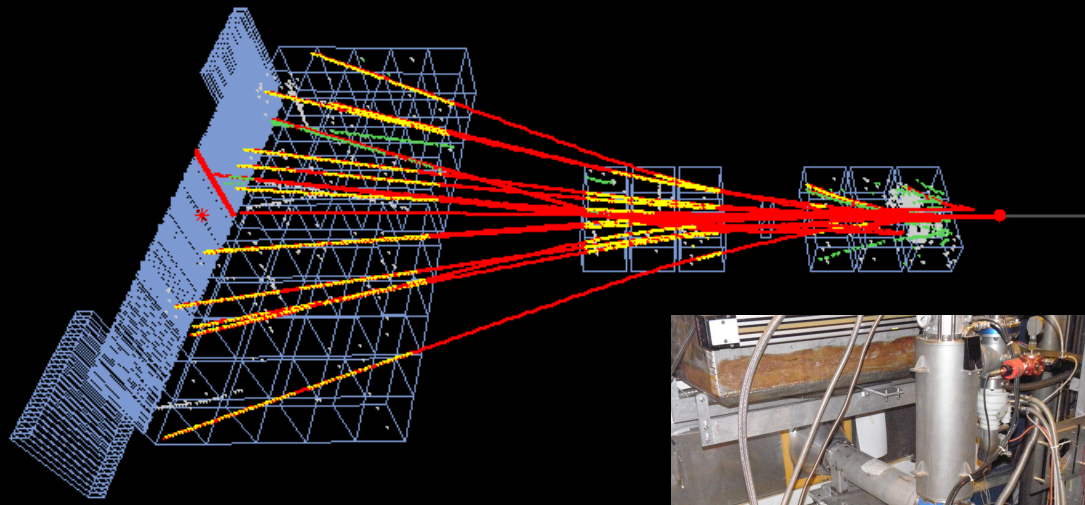
p+p at 40 GeV/c 6M events



p+p at 80 GeV/c 1+... M events

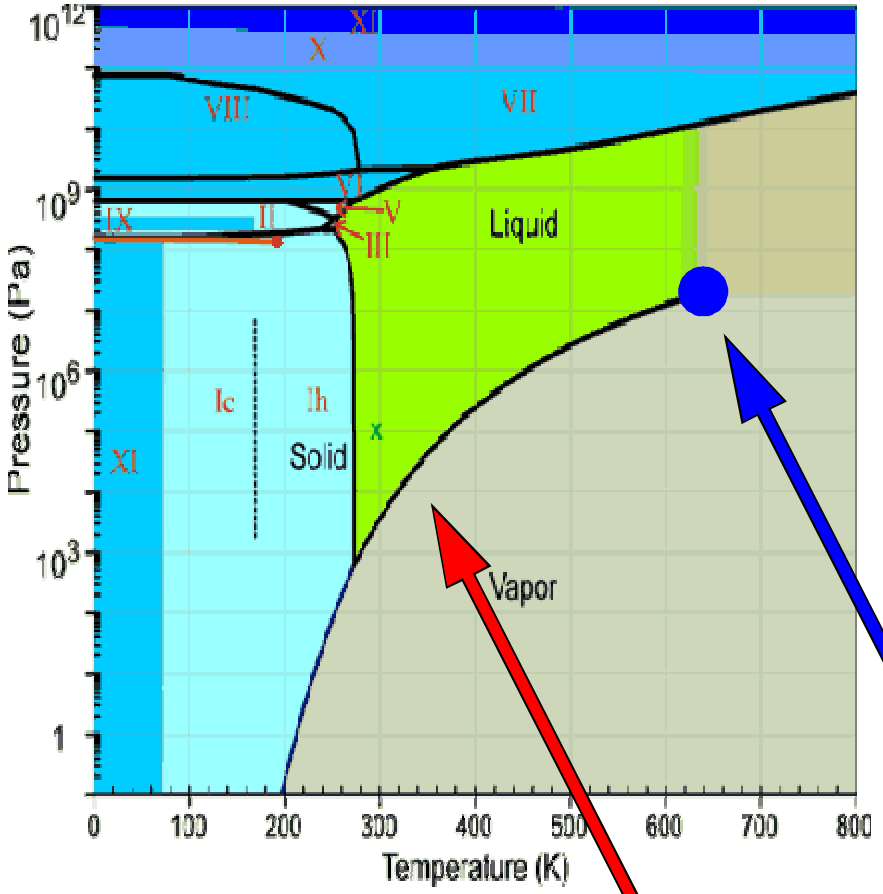


p+p at 158 GeV/c 4M events

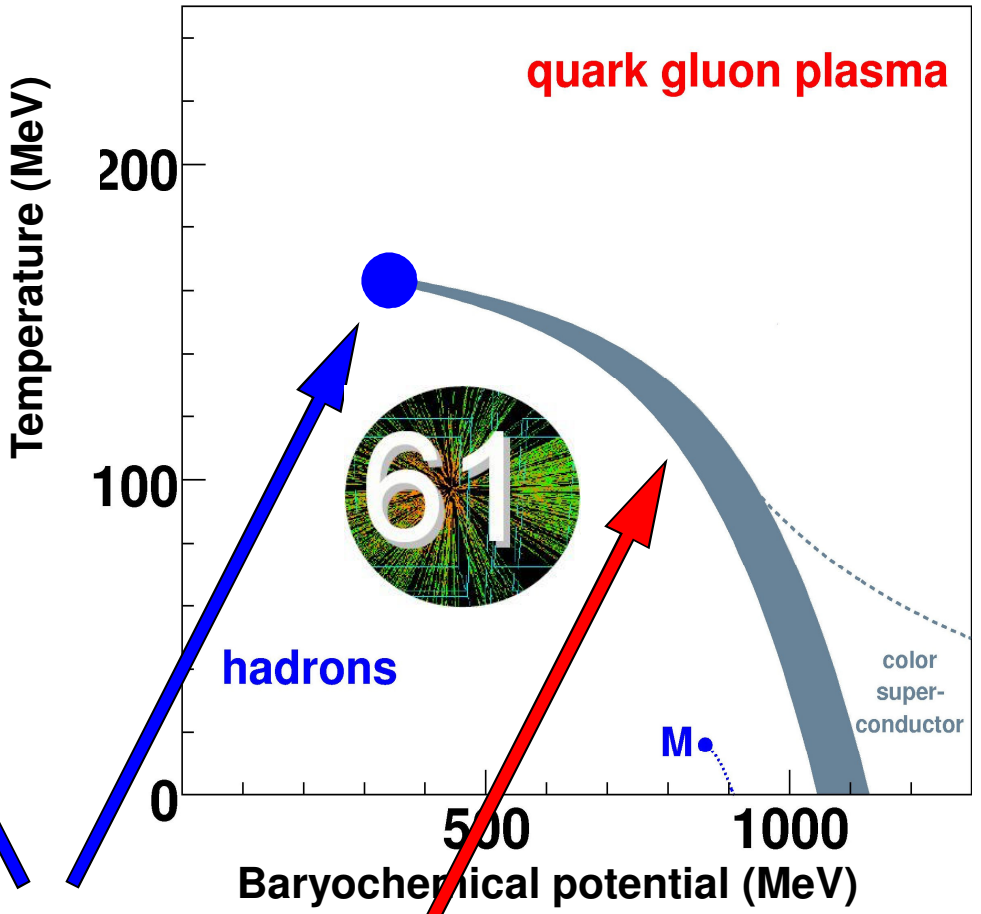


Searching for the critical point

water

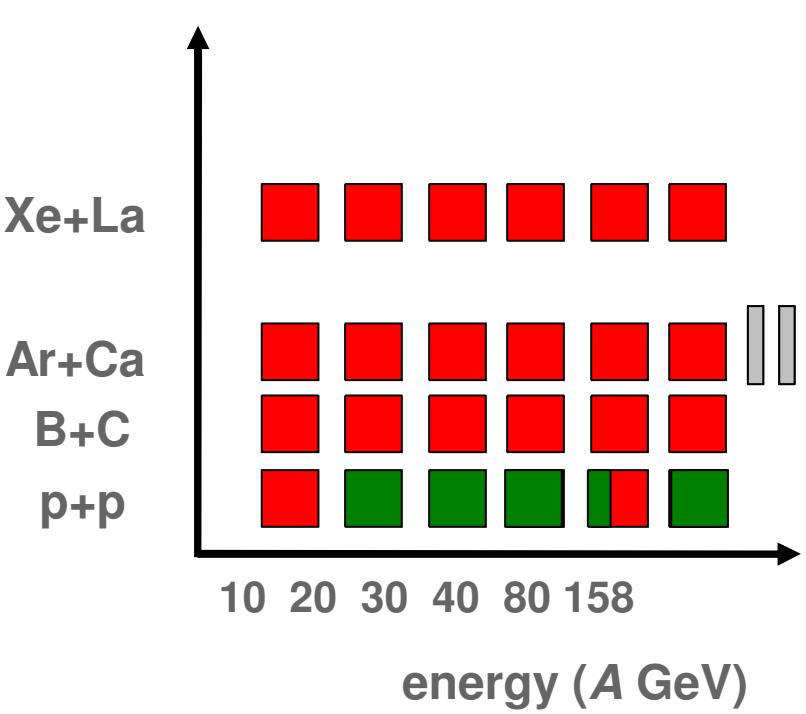


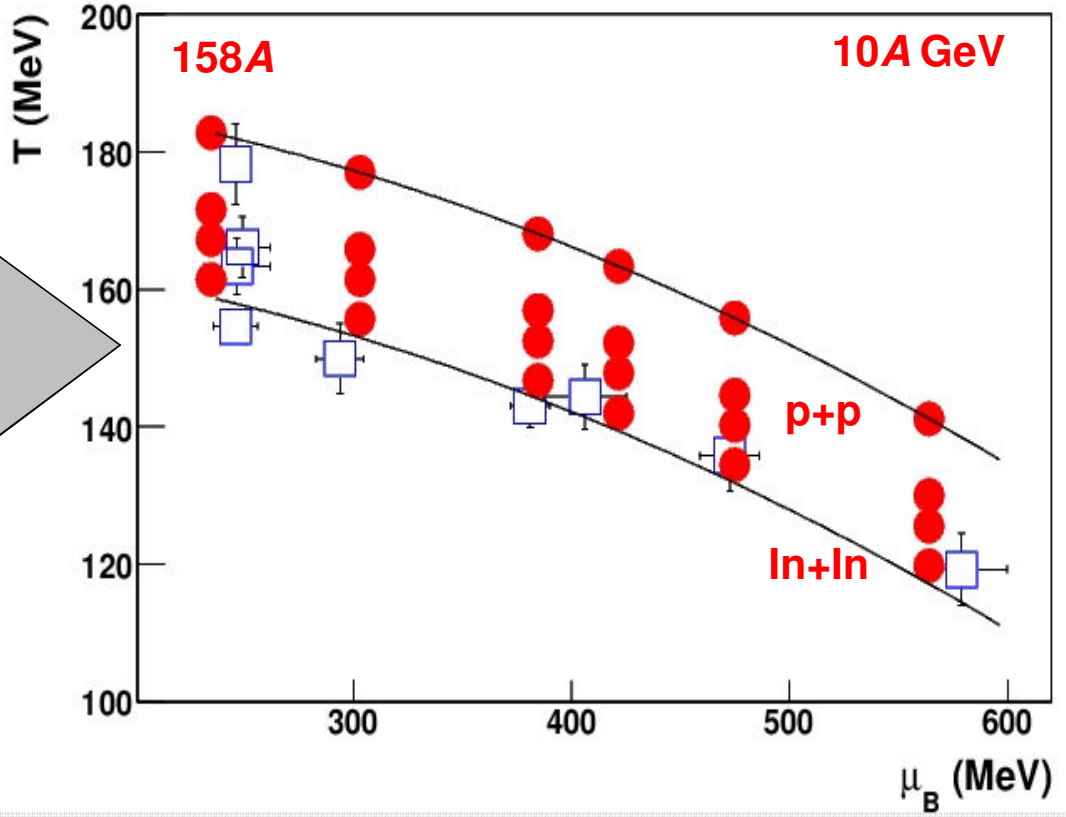
strongly interacting matter

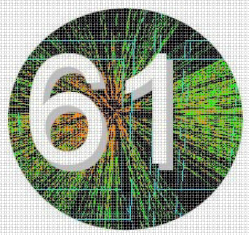


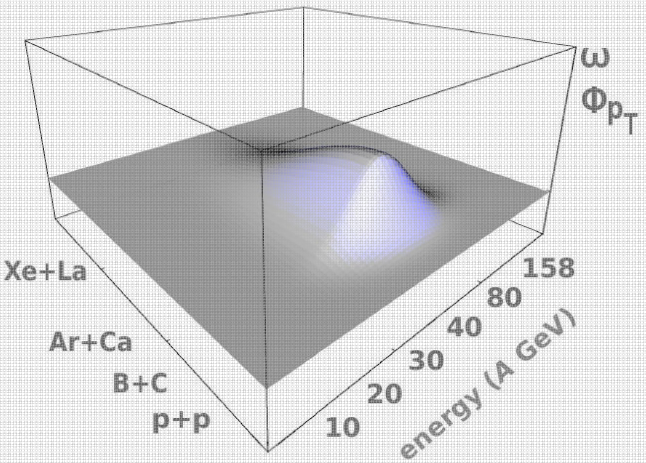
1st order phase transition

Searching for the critical point





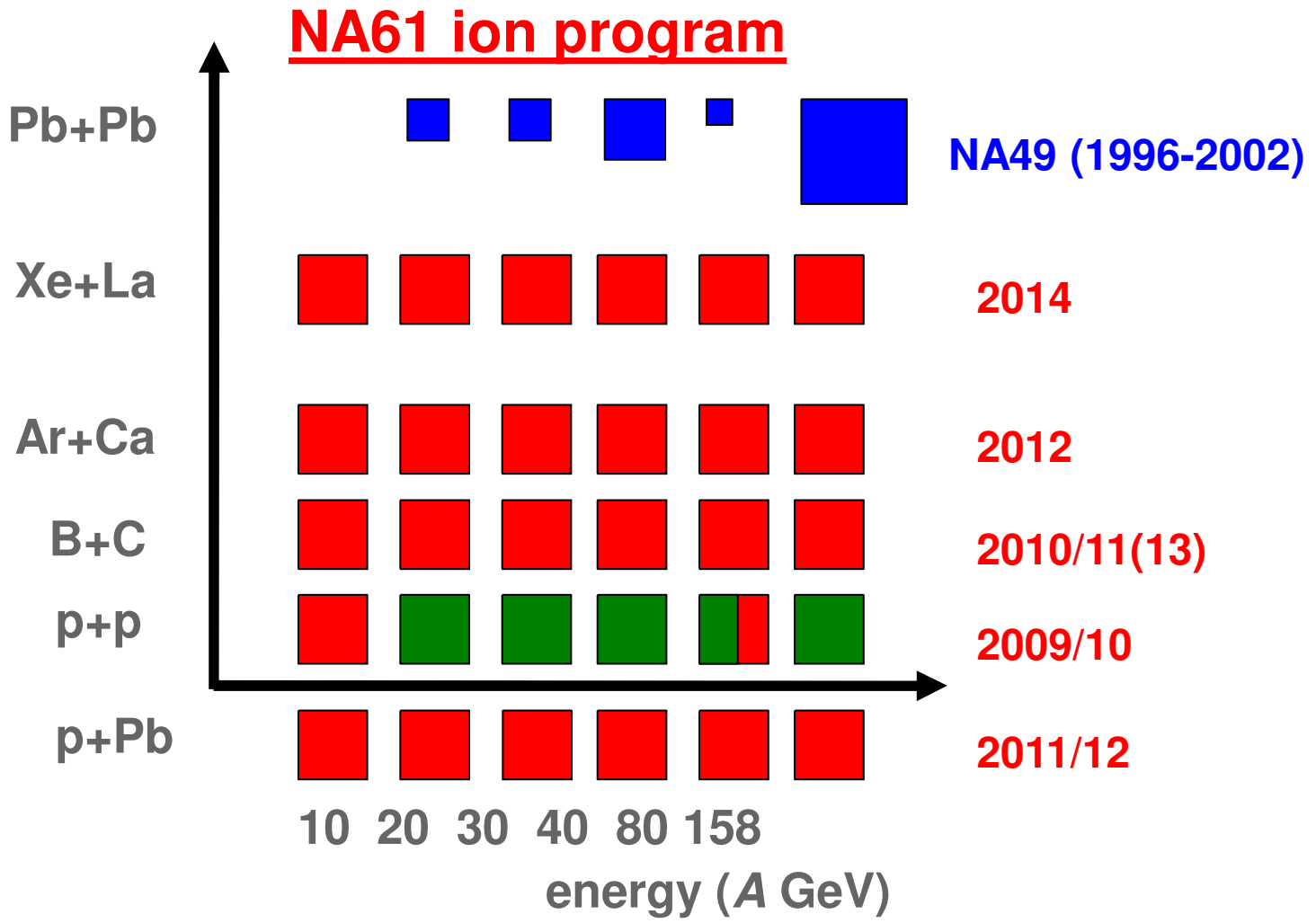




Search for the hill of fluctuations

Discovery potential

Revised data taking schedule with ion beams



The first 2D scan in history of A+A collisions

History of NA61 ion beam requests

2006: Proposal: primary C, S and In ions, start in 2009

2007: SPSC: recommended run with primary S ions

2008: RB: compatibility with the I-LHC (Pb (Ar, Xe))

2009: Addendum 4: use of secondary ion beams from primary Pb beam fragmentation, start in 2011

2009: changes in the LHC and I-LHC schedules, collaboration with Beam Department

2009: Addendum 5: use of primary and secondary ions, start in 2011(12) (test in 2010(11))

The NA61 revised data taking plan

Beam Primary	Beam Secondary	Target	Energy (A GeV)	Year	Duration days/MDs	Physics	Status
p	p	p	400 158	2010	77 d	High p_T	*recommended*
Pb	^{11}B	none	20,80 20,80	2010	10 MDs	FS test-1	*to be discussed*
p	p	Pb	400 158	2011	77 d	High p_T	*recommended*
Pb	^{11}B	C	10,20,30,40,80,158 10,20,30,40,80,158	2011	20 d	FS test-2	*to be discussed*
p	p	Pb	400 10,20,30,40,80,158	2012	6x8 d	CP,OD	*recommended*
Ar		Ca	10,20,30,40,80,158	2012	6x8 d	CP,OD	*recommended*
Pb	^{11}B	C	10,20,30,40,80,158 10,20,30,40,80,158	2013	6x10 d	CP,OD	*to be discussed*
Xe		La	10,20,30,40,80,158	2014	6x8 d	CP,OD	*to be discussed*

FR test-1

secondary (FR test-2)

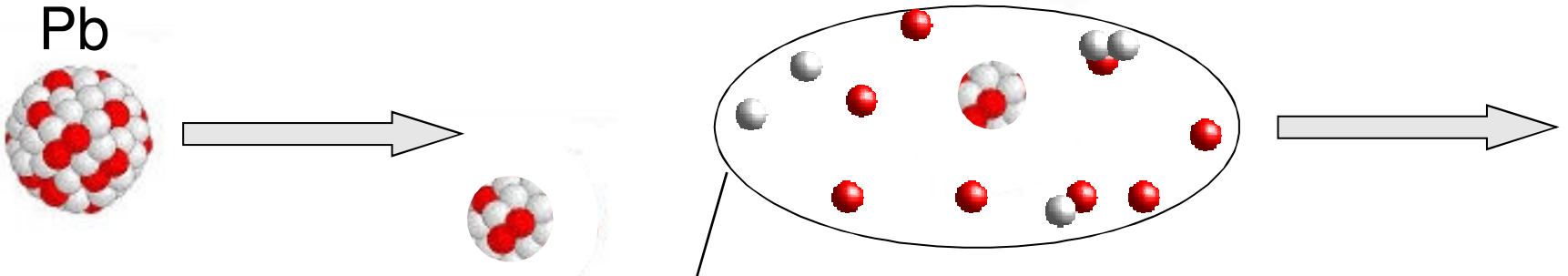
primary

(secondary)

primary

Secondary Ion Beam Line for NA61

The basic idea

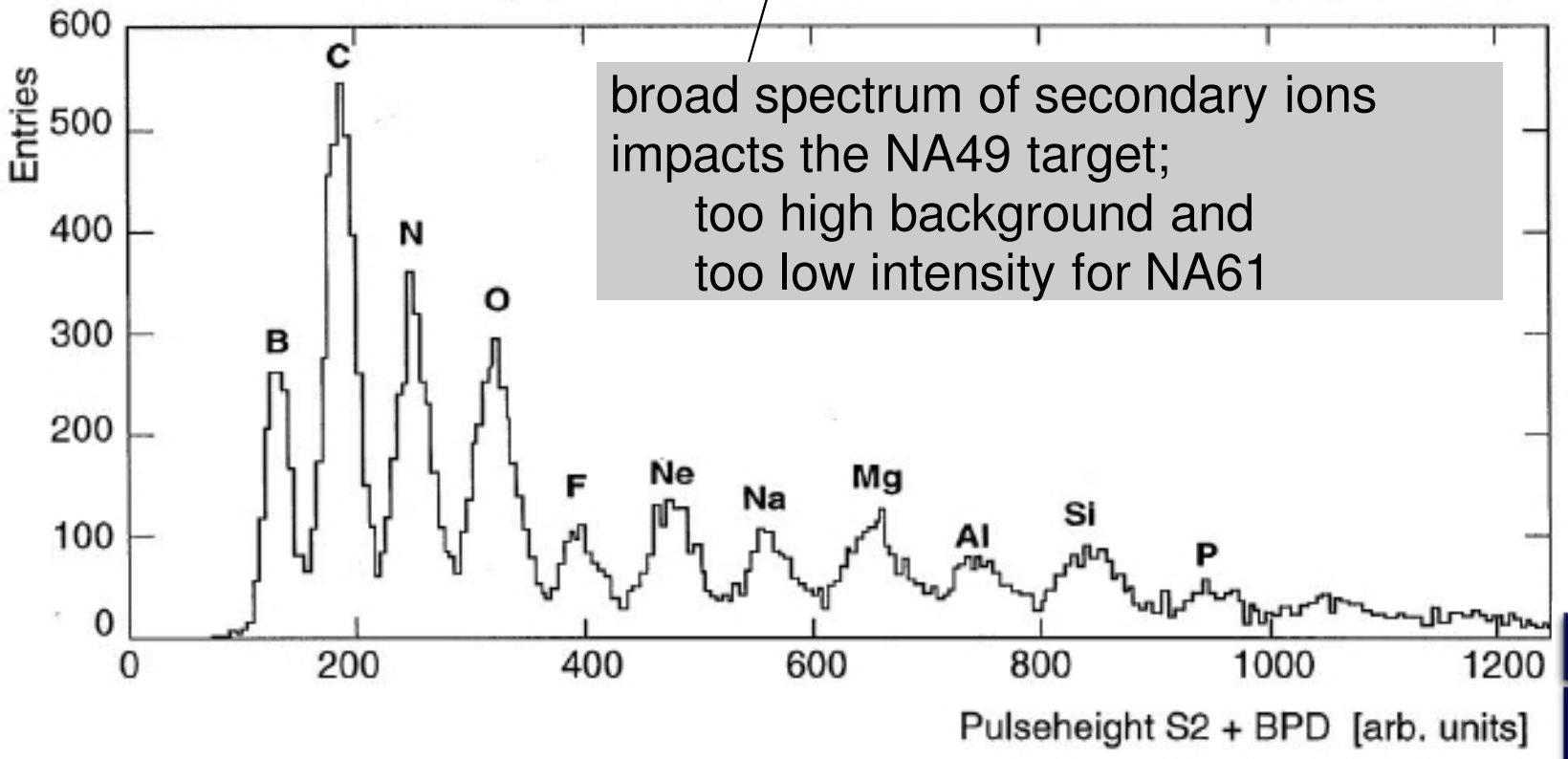


primary Pb beam from the SPS

fragmentation target

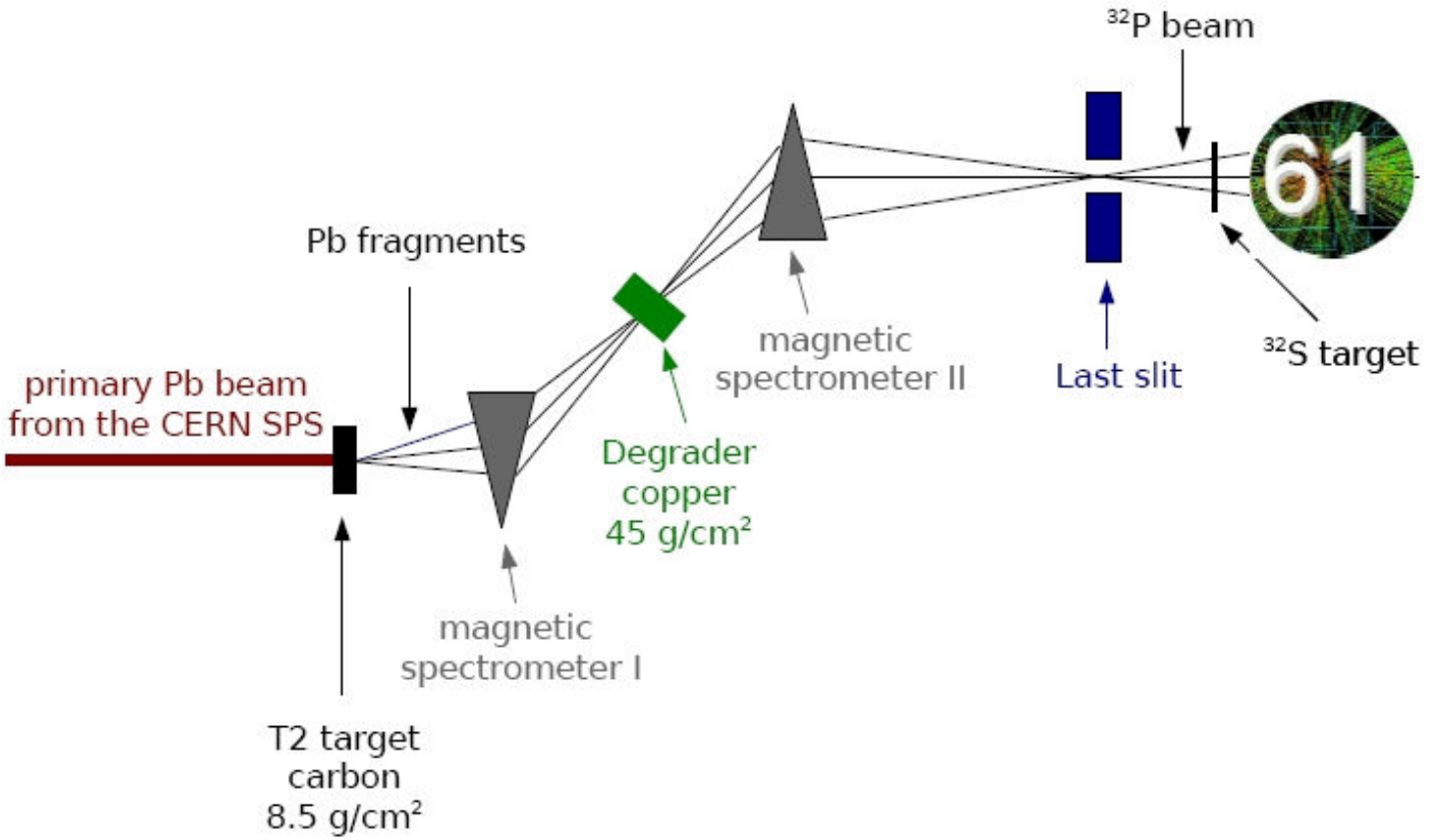
secondary light ion beam to NA49

The pilot NA49 studies



broad spectrum of secondary ions impacts the NA49 target;
too high background and
too low intensity for NA61

Secondary Ion Beam Line for NA61:



-selects beam of nuclei with close Z and A,
-further ion identification possible by Z (charge) measurements
-momentum per nucleon cannot be changed

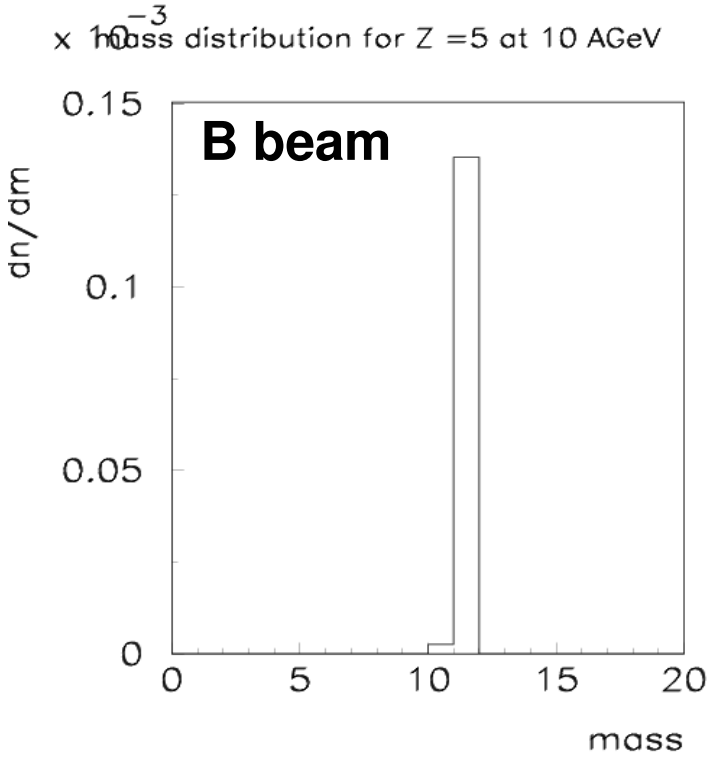
Performance with secondary ^{11}B beam

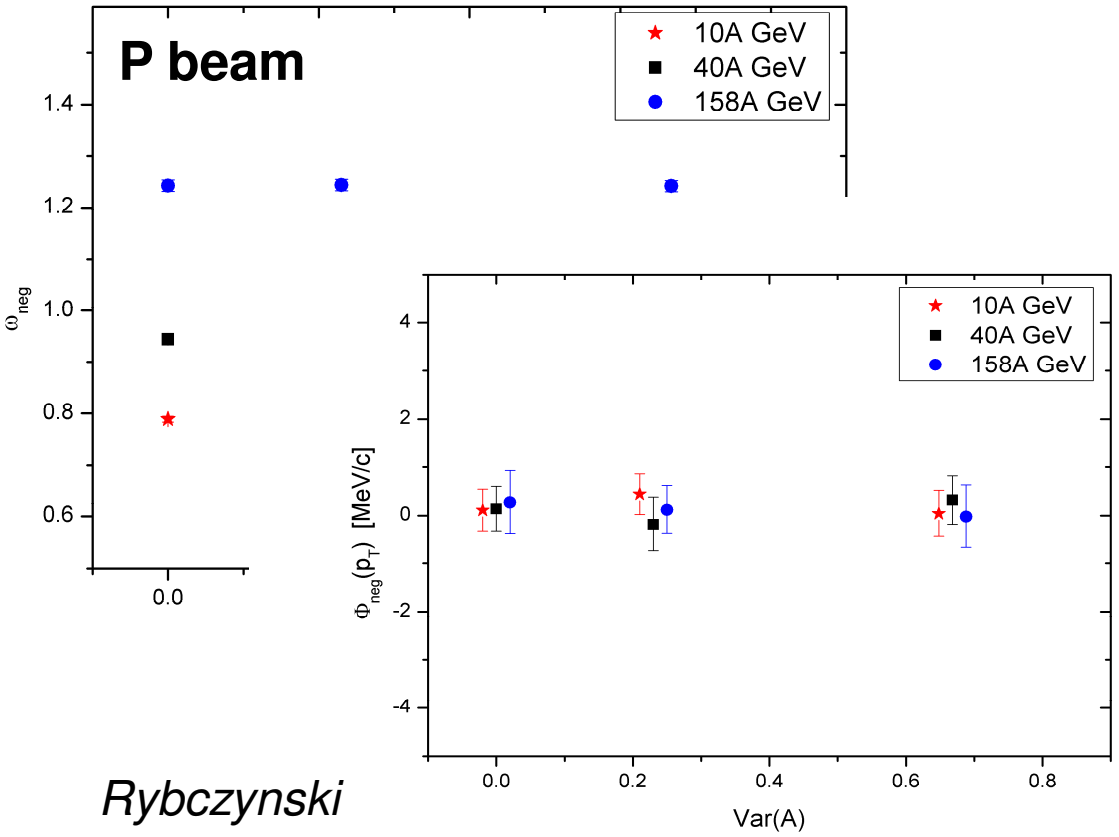
Summary based on detailed results of simulations Presented in Addendum 5:

At low energies the event rate 2 times lower than for the primary beams

High beam purity

Insignificant increase of systematic uncertainties





Stroebele

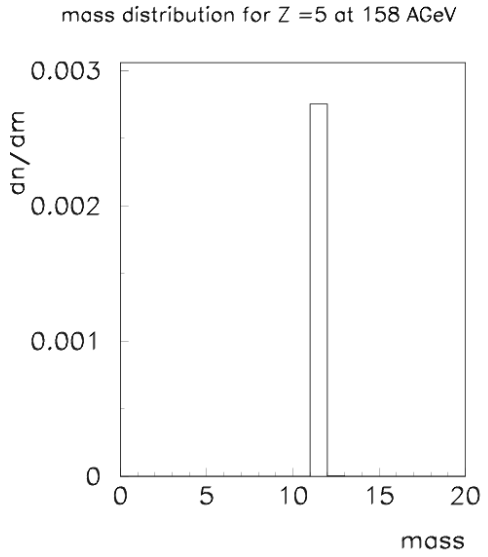
Rybczynski

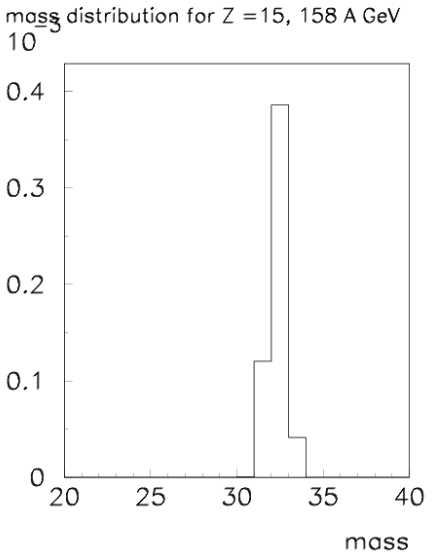
Performance with secondary heavy ion (Sn) beam

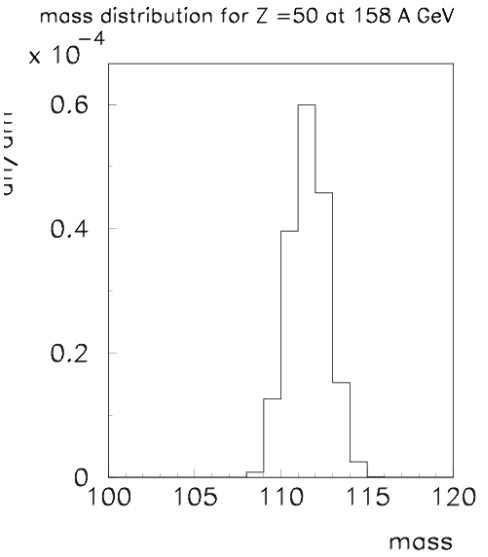
Summary based on detailed results of simulations Presented in Addendum 5:

At low energies the event rate up to 10 times lower than for the primary beams

Significant contamination of un-wanted ions







The NA61 ion program is not possible with secondary ion beams alone

Detector upgrades for runs with ion beams

Projectile Spectator Detector:
- -construction of modules in progress,
- -tests of the read-out electronics and integration with the NA61 DAQ,
- -expected to be ready for 2011

He beam pipe:
- -technical design ready,
- -construction of the the prototype and installation test to be started soon,
- -expected to be ready in 2011

Summary

Analysis of the 2007 pilot data:
- **obtained preliminary pion spectra and inelastic cross section for p+C interactions at 31 GeV/c,**
- **spectra of K and p to be expected within next months**

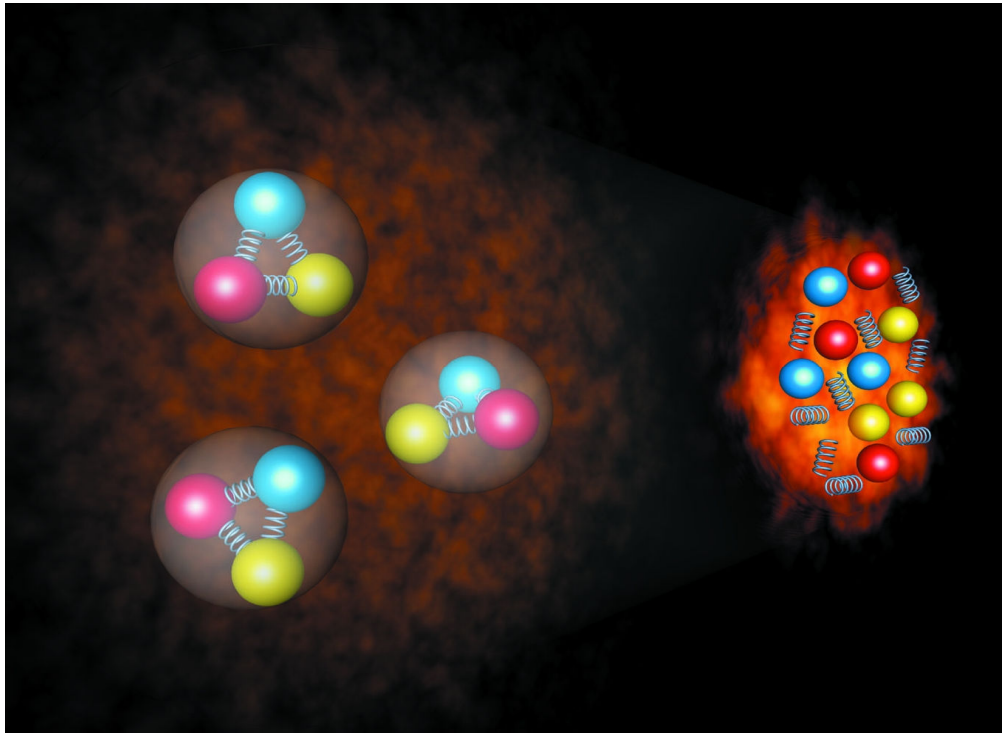
2009 run:
- **detector upgrades are completed and fully operational**
- **very successful data taking !!!**

Data taking with ion beams:
- **the revised schedule is proposed, it combines running with primary and secondary ion beams**
- **the schedule is agreed with the representatives of the Beam Department**
- **work on the detector upgrades for runs with ion beams is in progress**

Additional slides

Onset of deconfinement

hadrons mixed QGP



AGS SPS RHIC

collision energy

AGS SPS RHIC

hadron production properties

Kink

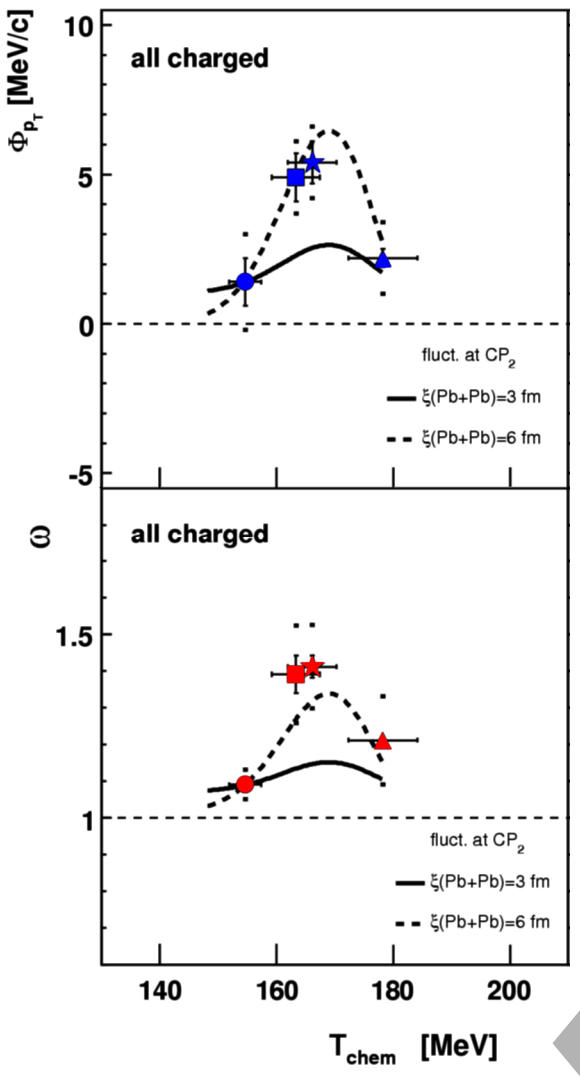
Horn

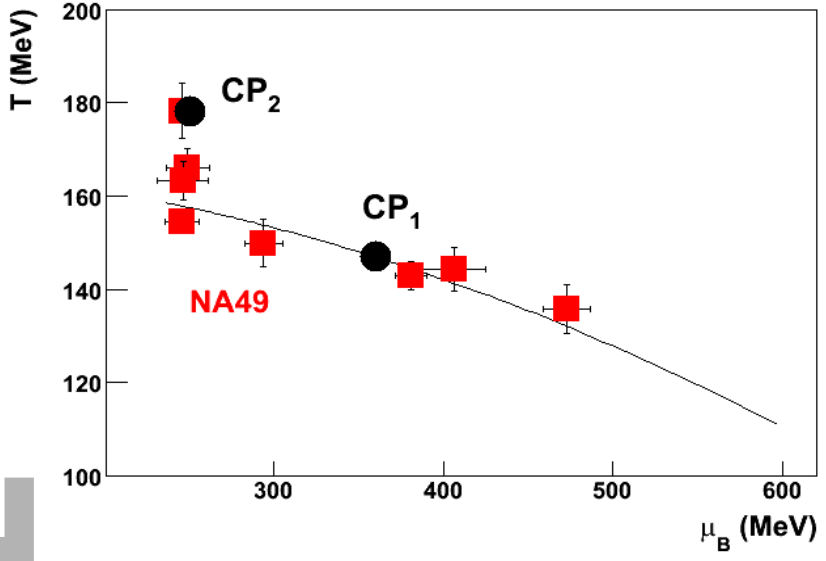
Step

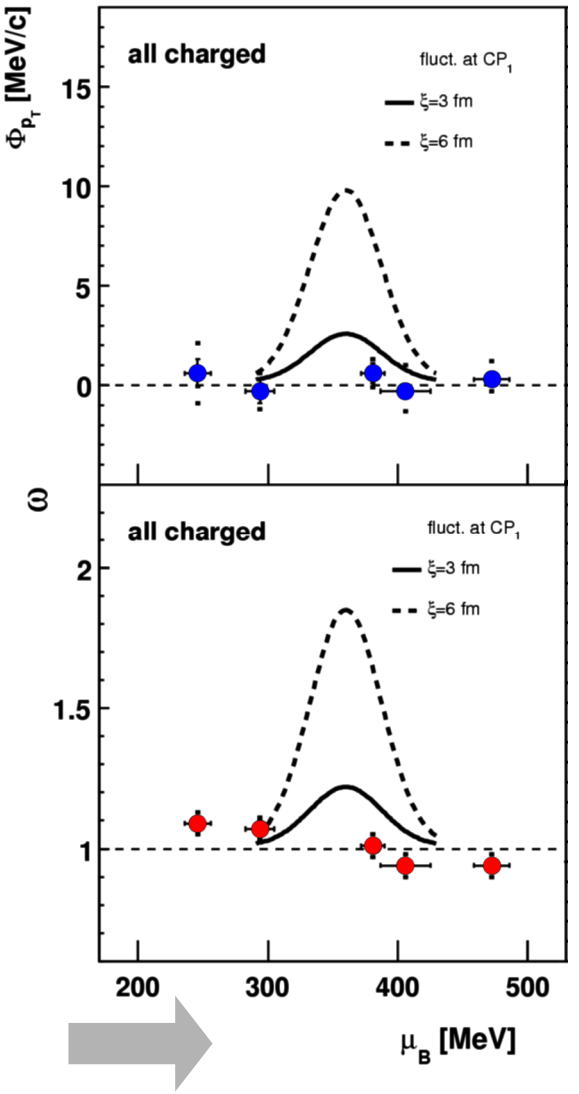
collision energy

NA49 results (PRC77:024903): evidence for the onset of deconfinement at the low CERN SPS energies

NA49 search for the critical point







First hint of the fluctuation hill?

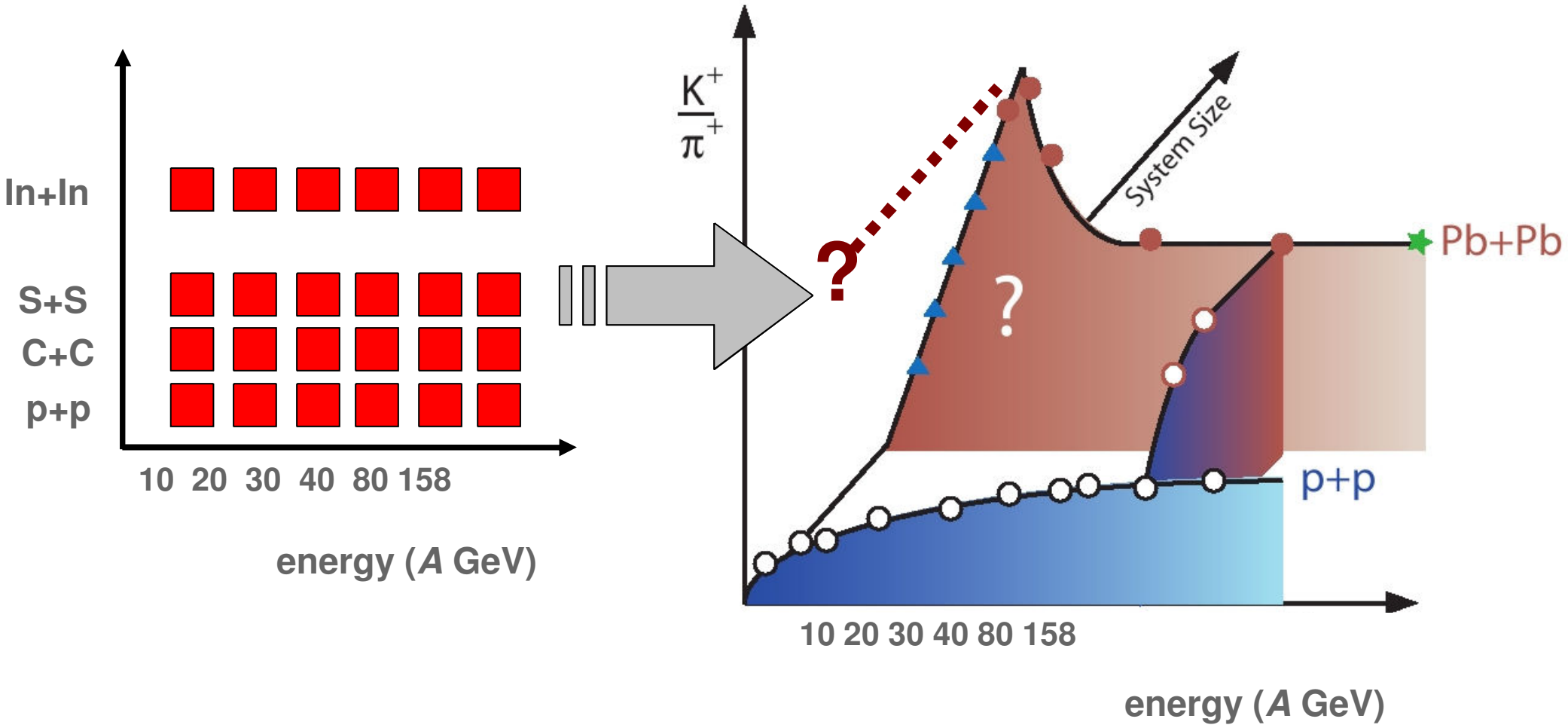
PRC78:034914
PRD60:114028
arXiv:0810.5510

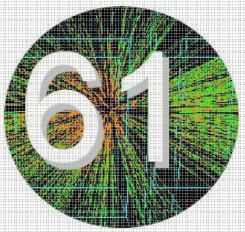
Experimental landscape of complementary programs of nucleus-nucleus collisions around the SPS energies

Facility:	**SPS**	**RHIC**	**NICA**	**SIS-100** (SIS-300)
Exp.:	**NA61**	**STAR** PHENIX	**MPD**	**CBM**
Start:	**2011(2)**	**2011**	**2015**	**2017** (2019)
Pb Energy: (GeV/(N+N))	**4.9-17.3**	**4.9-50**	**≤9**	**≤5** (<8.5)
Event rate: (at 8 GeV)	**100 Hz**	**1 Hz(?)**	**≤10 kHz**	**≤10 MHz**
Physics:	**CP&OD**	**CP&OD**	**OD&HDM**	**HDM** (OD)

CP – critical point
OD – onset of deconfinement, mixed phase, 1st order PT
HDM – hadrons in dense matter

Study the onset of deconfinement

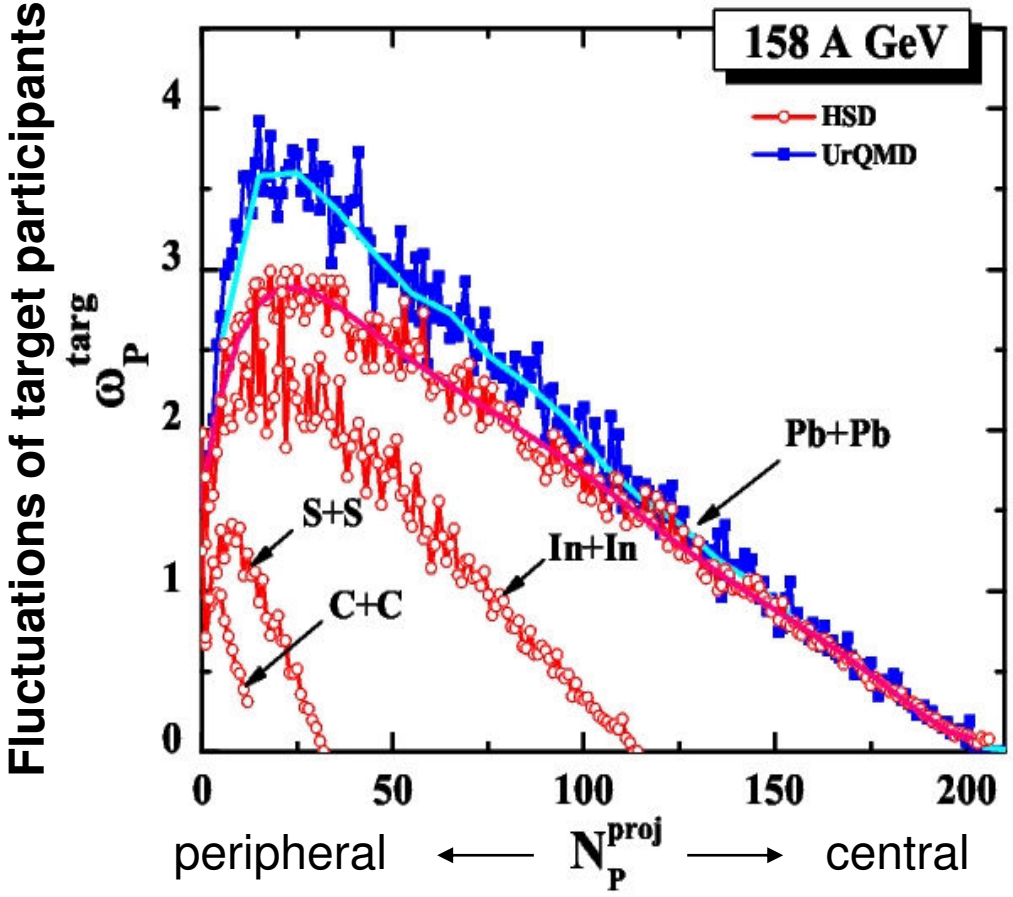




Search for the onset of the horn in collisions of light nuclei

Precision measurements following the NA49 discovery

Central collisions of light and medium size nuclei are required for the proposed fluctuation studies



Event-by-event fluctuations in the number of interacting (participant) nucleons are the main source of the background in the fluctuation studies

The fluctuations of the number of projectile participants are suppressed by selecting collisions with fixed number of projectile spectators (in NA61 measured by PSD)

The fluctuations of the number of target participants can be suppressed only by selection of very central collisions

Konchakovski et al., Phys. Rev. C 73, 034902