NAGI/SHINE IN BRIEF

- Facility
- Strong Interactions
- Neutrinos
- Cosmic-Rays
NA61/SHINE - UNIQUE MULTIPURPOSE FACILITY
HADRON PRODUCTION IN $n+p$, $n+A$, $A+A$
AT 13A - 150A (400) GeV/$c$
ACCELERATION CHAIN

PRIMARY BEAMS:
- PROTONS AT 400 GEV/C
- IONS (Ar, Xe, Pb) AT 13A-150A GEV/C

SECONDARY BEAMS:
- HADRONS (π⁺⁻, K⁺⁻, p/̅p) AT 13-400 GEV/C
- IONS (Br) AT 13A-150A GEV/C
NAGI/SHINE DETECTOR

Precise measurements of properties of produced particles: electric charge, mass momentum vector.
**STRONG INTERACTIONS**

What happens when strongly interacting matter gets hotter/denser and its volume changes?
NAGI/SHINE:

- PHASE TRANSITION VS VOLUME
- SEARCH FOR CRITICAL POINT
NUCLEI – THE LARGEST DROPLETS OF STRONGLY INTERACTING MATTER IN LAB
EVIDENCE FOR PHASE TRANSITION AT SPS AND ITS VOLUME DEPENDENCE
SEARCH FOR CRITICAL POINT

FLUCTUATIONS VS ENERGY AND VOLUME

UP TO NOW NO EVIDENCE FOR EXPECTED "HILL" OF FLUCTUATIONS
DATA COLLECTION STATUS AND PLANS

system size

beam momentum [A GeV/c]

Pb+Pb
Xe+La
Ar+Sc
Be+Be
p+Pb
p+p

2016/18
2017
2015
2011/12/13
2012/14/17
2009/10/11
**The Neutrinos**

**What happens with neutrinos flying across United States and Japan?**

- Oscillations: rotation of states during propagation

\[
|\nu(x_0)\rangle = |\nu_e\rangle = c|\nu_1\rangle + s|\nu_2\rangle
\]

One given flavour produced by weak interaction

\[
|\nu(x)\rangle = c|\nu_1\rangle e^{i(Et - \mathbf{k}_1 \cdot \mathbf{x})} + s|\nu_2\rangle e^{i(Et - \mathbf{k}_2 \cdot \mathbf{x})}
\]

Mass eigenstates propagate at different velocity

\[
P(\nu \rightarrow \nu_\mu) = |\langle \nu_\mu | \nu(t) \rangle|^2
\]

Weak interaction selects component of one flavour
DUNE - LONG-BASLINE NEUTRINO OSCILLATION EXPERIMENT

Measurements for T2K in Japan are completed

NAGI/Shine measurements for determination of initial neutrino flux started in 2016
**Cosmic Rays**

**What is the origin of very high energy cosmic rays?**

**Active Galaxies with Supermassive Black Holes**
Measuring cosmic-ray composition

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
CHARGED HADRONS IN $\bar{\nu} + C$ AT 158 AND 350 GeV/c

$$(\text{NA61 DATA}) / \text{EPOS}$$

NA61 DATA ARE USED FOR FITTING MODELS RELEVANT FOR SIMULATIONS OF EXTENSIVE AIR SHOWERS

$P_{T} \text{ [GeV/c]}$

$h^{-} \text{ at 350 GeV/c}$

$p \text{ [GeV/c]}$
National Nuclear Research Center, Azerbaijan
Faculty of Physics, University of Sofia, Bulgaria
Ruder Boskovic Institute, Croatia
LPNHE, University of Paris VI and VII, France
Karlsruhe Institute of Technology, Germany
Fachhochschule Frankfurt, Germany
Institut für Kernphysik, Goethe-Universität, Germany
Nuclear and Particle Physics Division, University of Athens, Greece
Wigner RCP, Hungary
Institute for Particle and Nuclear Studies (KEK), Japan
University of Bergen, Norway
Jan Kochanowski University in Kielce, Poland
National Center for Nuclear Research, Poland
Institute of Physics, Jagiellonian University, Poland
Institute of Physics, University of Silesia, Poland
Faculty of Physics, University of Warsaw, Poland
Department of Physics and Astronomy, University of Wroclaw, Poland
Faculty of Physics, Warsaw University of Technology, Poland
IFJ PAN, Poland
Institute for Nuclear Research, Russia
Joint Institute for Nuclear Research, Russia
St. Petersburg State University, Russia
National Research Nuclear University MEPhI, Russia
University of Belgrade, Serbia
ETH Zürich, Switzerland
University of Bern, Switzerland
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