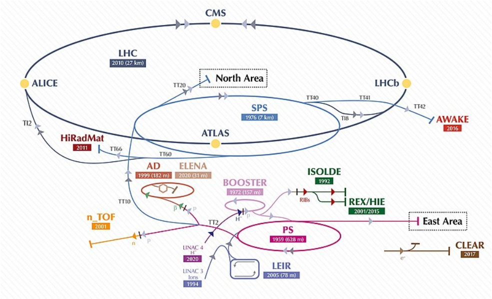
Specialization semester at LPNHE
Mid term presentation

Claire Dalmazzone

15/11/2021

Outline

NA61/SHINE: A fixed target experiment

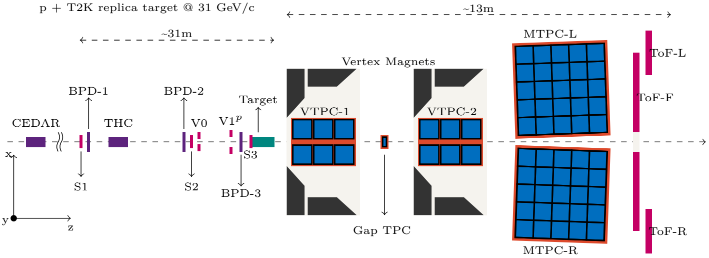


NA61/SHINE: A fixed target experiment

- Multipurpose fixed target experiment
- The incident beam is a secondary beam produced by the collision of a primary proton or ion beam (extracted from CERN SPS) on Beryllium targets.
- Applications: Study hadronic production to
  - improve cosmic ray air shower models
  - study the critical point of strong interaction with nucleus/nucleus collisions
  - improve neutrino flux predictions for neutrino experiments such as T2K and Fermilab ν beamline

NA61/SHINE: experimental setup

Setup used for T2K measurements



Currently being upgraded

NA61/SHINE: experimental setup

Upstream detectors

- CEDAR and THC: Cherenkov detectors for incoming PID (offline selection cut)
- BPDs: proportional gas chambers, monitor the beam profile
- S_i: scintillators used for the triggers
- V_i: veto scintillators used for the triggers

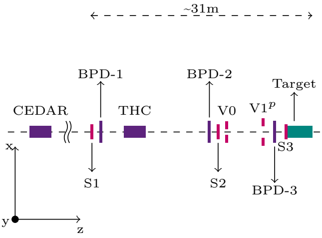


Figure 2: Upstream part of NA61/SHINE setup

NA61/SHINE: experimental setup

Downstream detectors: TPCs tracker (measure energy deposit)

- VTPCs: Vertex TPCs, measure charge and momentum
- Gap TPC: measure charge and momentum in forward region
- MTPCs: Main TPCs
- TOF wall: measure time of flight

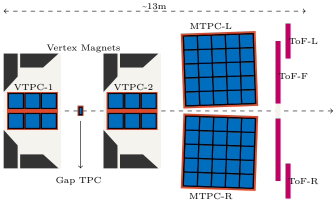
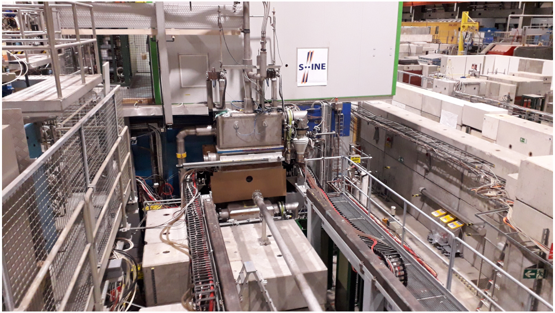


Figure 3: Downstream part of NA61/SHINE setup

Detector work: the upgrade

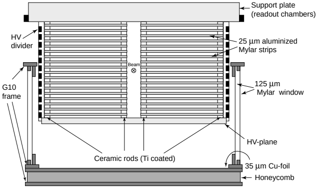


Increase the readout rate by a factor 10!

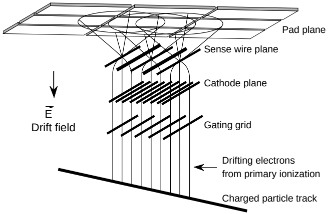
My contribution: helped change the electronics of the MTPCs

The TPCs

- Gas chambers (Ar and CO_2) with MWPC
- Uniform electric field with stepwise divided voltage: 25μm wide aluminium strips around the chamber
- readout planes in proportional range with a $5 \cdot 10^4$ amplification
- x and y positions determined from the signal in the segmented pad plane
- z position determined with drift time



(a) VTPC



(b) signal generation

Electronic upgrade: installation

Figure 5: New electronic cards

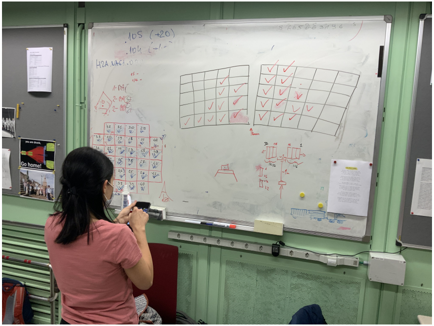
Figure 6: Installation on the MTPCs

25 sectors per MTPC
12 cards per sector

Front End cards (big one): reused from ALICE experiment
Input cards (small ones): to connect to the TPCs readout

Electronic upgrade: test

Output signal should be uniform through each channel (otherwise false contact or dead electronic)



Regularly test with a pedestal (~ 1 count) input signal

Electronic upgrade: test

VTPCs electronic upgrade finished

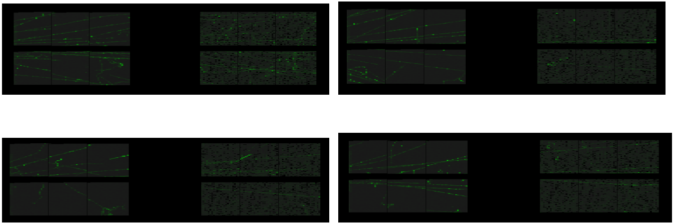


Figure 7: Tracks of particles produced in p+Pb interactions observed in the VTPCs with the new electronics

Analysis work: Hadrons spectra with NA61/SHINE

Hadron production in NA61/SHINE: comparison between experimental data and simulations

Hadrons spectra with NA61/SHINE

Hadron production in NA61/SHINE: comparison between experimental data and simulations.

- $\pi^{\pm}$, $\mathrm{K}^{\pm}$, p, $\bar{\mathrm{p}}$, Λ, $\bar{\Lambda}$ and K_S^0 (identification process explained in back up slides)
- Produced in π^{-}- C collisions at beam momenta 158 and 350 GeV
- Experimental data from 2009 with two data sets:
  - target Removed: R
  - target Inserted: I
- **GOAL**: compare double-differential p - p_T spectra extracted from experimental data to simulation results from FLUKA and GiBuu codes

Application

- Tuning models of particle production in EAS for cosmic ray studies
- Pions are the most abundant projectiles in EAS
- Carbon is used as a proxy to Nitrogen (atmosphere).

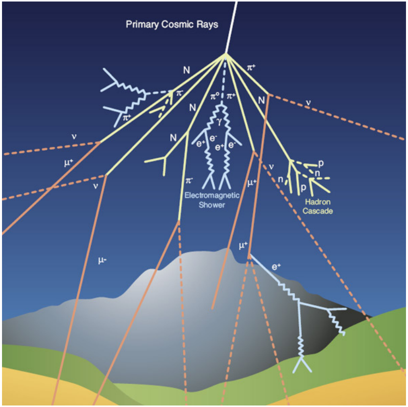


Figure 8: Illustration of cosmic ray induced EAS

Derivation of the spectra

Experimental Data

$$\frac{1}{N_{prod}}\frac{d^2n}{dpdp_T} = \frac{C_{sim}}{\hat{N}_I - b\hat{N}_R}\frac{\hat{n}_I - b\hat{n}_R}{\Delta p \Delta p_T}$$

- $\hat{N}$: number of events
- $\hat{n}$: number of particles in the bin
- b: target removed-factor
- C_{sim}: factor derived from simulation to correct the bias on $\frac{\hat{n}}{\hat{N}}$
- Δp and Δp_T: bins width

Hadrons flux generation with FLUKA and GiBuu

Hadrons flux generation with:

- **FLUKA** (http://www.fluka.org/fluka.php): MC that simulates propagation and interactions of particles in matter. It uses three models according to interaction type and energy. Usually gives the best predictions of the experimental data in hadronic interactions.
- **GiBuu** (https://gibuu.hepforge.org/trac/wiki): Fortran Code for a unified theory and transport framework for elementary reactions on nuclei and heavy-ion collisions.

Derivation of the spectra

Simulation results

- One histogram per p bin
- Normalized by the number of events
- Each bin-value is divided by:
  - Δp_T (varying size)
  - Δp (constant in log scale)

NB: The spectra are multiplied by 10^m with $m \in \{0, 1, 2\}$ depending on the p bin for the readability of the plots (several p bins per plot).

π^+ at $p_{\text{beam}} = 158\text{GeV/c}$

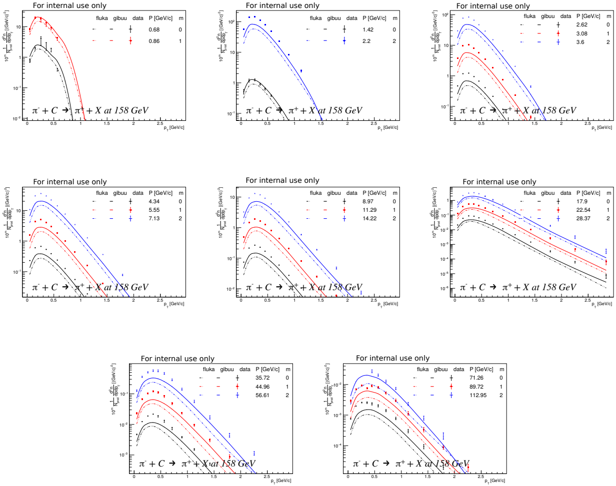


Figure 9: π^+ production spectra in π^--C interactions at $p_{\text{beam}} = 158\text{GeV/c}$.

π^+/π^- at $p_{beam} = 158$ GeV

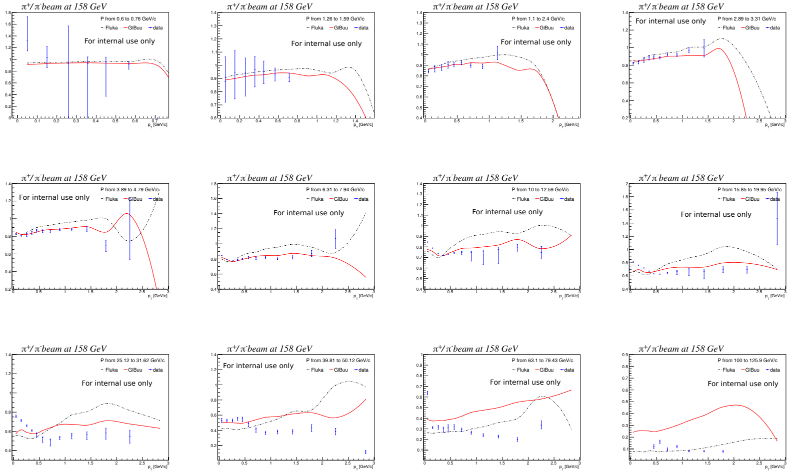


Figure 10: Ratios of π^+ and π^- production spectra in π^--C interactions at $p_{\text{beam}} = 158$ GeV/c

Conclusions

- Neither Fluka nor GiBuu is able to predict the experimental data at $p_T \geq 1.5$ GeV.
- GiBuu predictions are usually more consistent with the experimental data at small p_T (except for $p/\bar{p}$).
- For pions especially, the discrepancy between data and simulation increases with increasing momentum.
- Very high discrepancy data/simulation for $\Lambda/\bar{\Lambda}$ (can be produced directly or via the weak decay of heavier baryons)

What's next?

Hadrons spectra from p - C interactions for ν_μ beam applications

- Produce evolution plots of the double differential $p-\theta$ (in lab. frame) production spectra for an incident beam momentum of 31 (T2K), 60 and 120GeV (Fermilab)
- Compare experimental data (2009) to FLUKA and GiBuu generator results

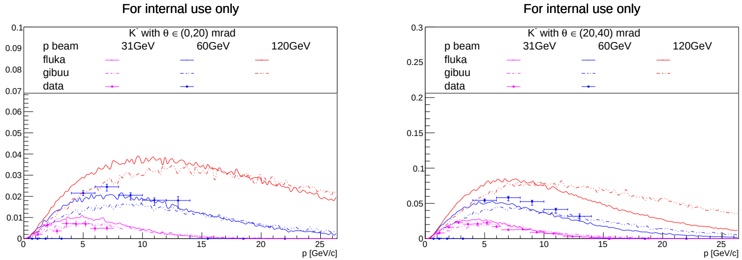


Figure 11: Evolution plots of K^- production spectra in p-C interactions for $p_{beam} = 31$, 60 and 120 GeV.

Questions?

Thank you for your attention!

Questions?

Back up slides

Back up slides

PID: dEdx analysis

Identification of outgoing charged particles

- Bethe formula:

$$\langle \frac{dE}{dx} \rangle = f(p, m)$$

- "Bethe crossings": degeneracy of the fitting templates for different particles in some p bins (analysis fails)
- Can also use tof measurement $m^2 = \frac{p^2}{c^2}(\frac{c^2 tof^2}{l^2} - 1)$

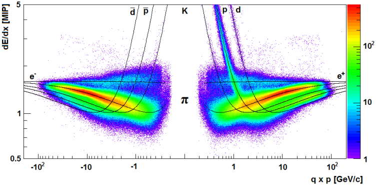


Figure 12: Example of energy deposit in TPCs along with theoretical curves

PID: V^0 analysis

Identification of outgoing V^0 particles

- **GOAL**: identify some neutral particles that decay in the experimental setup like Λ, $\bar{\Lambda}$ and K_S^0.
- **IDEA**: Consider each pair of negative and positive particles tracks with a small enough distance of closest approach
- Calculate the corresponding invariant mass distribution.
- Two contributions:
  - Flat background from uncorrelated pairs
  - Peaks at the V^0s masses

T2K measurement Triggers

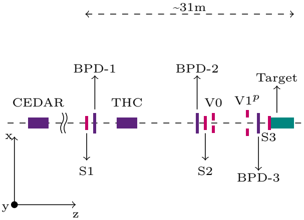


Figure 13: Upstream part of NA61/SHINE setup

T_1	$S_1 \cdot S_2 \cdot \bar{V}_0 \cdot \bar{V}_1' \cdot$ CEDAR $\cdot \bar{\text{THC}}$
T_2	$S_1 \cdot S_2 \cdot S_3 \cdot \bar{V}_1' \cdot$ CEDAR $\cdot \bar{\text{THC}}$
T_3	$S_1 \cdot S_2 \cdot S_3 \cdot \bar{V}_0 \cdot \bar{V}_1' \cdot$ CEDAR $\cdot \bar{\text{THC}}$
T_4	$S_1 \cdot S_2 \cdot S_3 \cdot \bar{V}_1'$

Table 1: Triggers used for T2K measurements

Reconstruction

- BPD reconstruction
- cluster finder in the TPCs
- track reconstruction (individual TPCs tracks matched together)
- momentum determination (in VTPCs)
- primary vertex reconstruction: track are extrapolated up to the dca with a beam track
- track refit and momentum determination with vertex constraint
- calculation of the maximum number of clusters which a given track can have (so-called potential points)
- energy loss and time of flight (hits on TOF matched to tracks)
- V^0 and Ξ finder

More on FLUKA and GiBuu

FLUKA

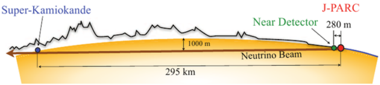
- **Inelastic hadron-nucleon interactions**:
  - Dual Parton Model above 5 GeV/c
  - Resonance production and decay model for $3-5$ GeV/c
- **Inelastic hadron-nucleus interactions**:
  - Glauber-Gribov cascade above 5 GeV/c
  - +Exciton-based preequilibrium model below 5 GeV/c

GiBuu

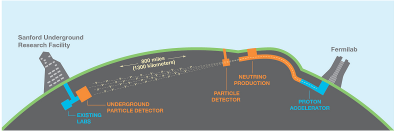
- Hadrons propagate in mean fields and scatter according to cross sections applicable to the energy range of a few 10 MeV to about 40 GeV
- At higher energies, pre-hadronic interactions are implemented to realize color transparency and formation time effects.

T2K and DUNE experiment

Long baseline neutrino oscillation experiments



(a) T2K neutrino beamline



(b) DUNE neutrino beamline

A hadron beam (mostly pions) is produced via the collision of an accelerated beam of protons on a graphite target. The decay of focused hadrons produce a beam of muon neutrinos with a given energy and direction. The beam profile is monitored by near detectors. The appearance of electron neutrinos is measured by a far detector.

LPNHE Paris 1971-2021 50 ans