Measurement of Nuclear Fragmentation Cross Sections with NA61/SHINE for a better understanding of the Propagation of Cosmic-Ray Nuclei in the Galaxy

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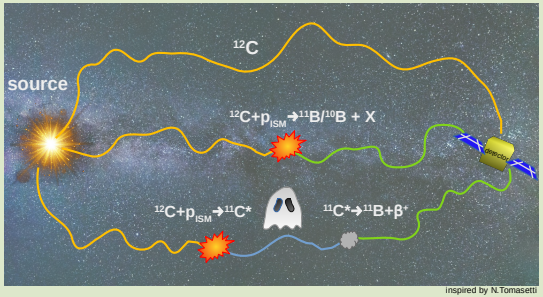
The Physics Case

- Interactions of primary cosmic ray nuclei with ISM produces secondary cosmic ray nuclei.
- Light secondary nuclei include Li, Be and B.
- Cross sections values are a crucial input for propagation models.



inspired by N.Tomasetti

fig 1: CR propagation in the galaxy

Ghosts in Space

- ^{12}C (primary) + p$_{ISM}$ → ^{11}C* + n (secondary & short lived)
- ^{11}C* decays to ^{11}B as ^{11}C* → ^{11}B + β$^+$
- Thus infamously categorized as 'Ghost nucleus'
- Contribution to the total secondary B production cross section is significant and necessary!

Current Status[1]

secondary-to-primary flux ratio → Galactic CR Propagation models ← nuclear fragmentation cross sections

uncertainties from recent AMS-02 measurements < 5%

current values induce ≈ 20% uncertainty

Eminent need of precise laboratory measurements of nuclear fragmentation cross sections

NA61/SHINE to the Rescue

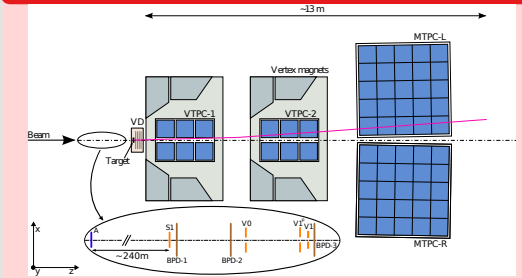
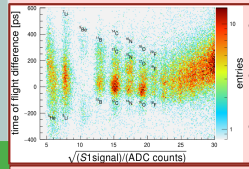


fig.2: NA61/SHINE setup

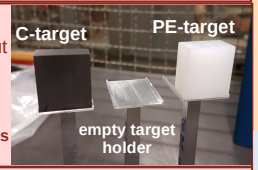
Experimental setup:

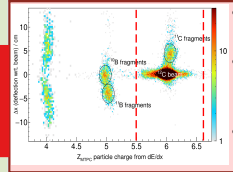
- **Multipurpose experiment on the H2 beam line at CERN[2].**
- **Aim: to study hadron-nucleus and nucleus-nucleus interactions with fixed targets.**
- **Nuclear interactions can be studied up to 400 GeV/c beam momentum.**
- **Main detectors: 2 Vertex and 2 Main TPCs(VTPCs & MTPC) VTPCs inside superconducting magnets.**



- **Pilot run** fragmentation data from 2018[3]
- secondary ion beam composition at NA61/SHINE from the H2 beam line
- time of flight(t_A-t_{S1}) and dE/dx in S1 used for isotope tagging

- Target setting: CH_2 (PE) & C and empty target (OUT) to correct for out-of-target interactions.
- d_{PE} = 1.5 cm & d_C = 1.0 cm
- effective reaction achieved: **C+p = (C+CH_2)–(C+C)–det. interactions**

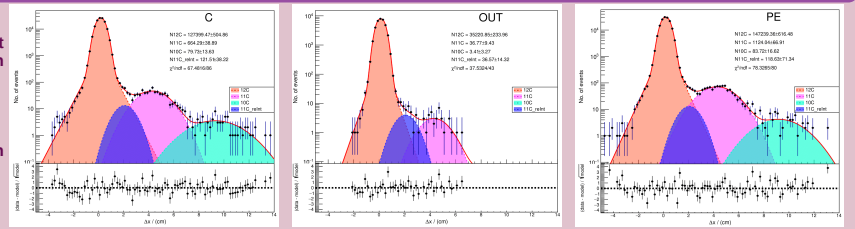




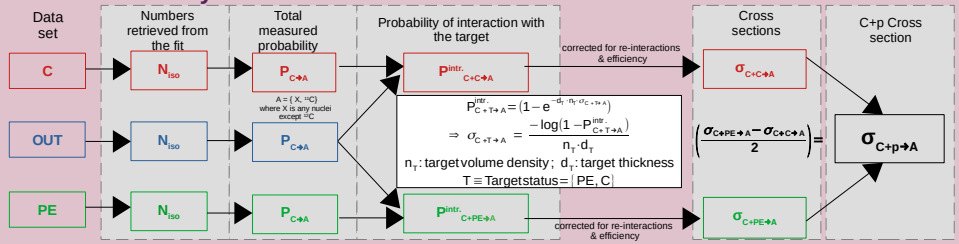
- Resulting fragments are well separated in the MTPC
- charge identification via energy deposit (dE/dx). C-isotopes selected as shown by the red dashed lines
- mass identification from Δx deflection in the magnetic field (relative to A/Z=2)

Analysis of Carbon Isotopes

Determination of isotope yields: Fit of the distribution of deflections Δx in the magnetic field relative to the beam. (position measurement in MTPC)



Flow of the Analysis:

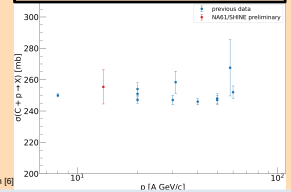


Results

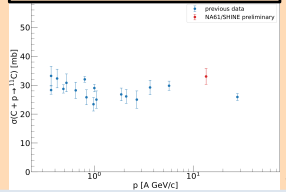
$\sigma_{C+p\to X}$ = 255 ± 11 mb

$\sigma_{C+p\to ^{11}C}$ = 33 ± 3 mb

C+p→X mass changing cross section



world data taken from [6]



world data taken from [1,5]

C+p→^{11}C production cross section

Conclusion & Outlook

- Measurement of ^{11}B&^{10}B[4] and ^{11}C (this work) with data from the 2018 pilot run on nuclear fragmentation with NA61/SHINE is in good agreement with previous data.
- Preliminary results prove the principle of performing fragmentation measurements at SPS energies.
- Dedicated data taking is planned for 2022: High statistics measurement of the production of light nuclear fragments (Li, Be, B) in light ion (C, N, O) fragmentation at the SPS[7].

References:
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[5] C. Evoli, R. Aloisio, and P. Blasi Phys. Rev. D99 no.~10, (2019) 103023.
[6] N. Abgrall et al., [NA61/SHINE Collab.] Eur. Phys. J. C76 (2016) 84.
[7] A. Aduszkiewicz et al., [NA61/SHINE Collab.],2018. CERN-SPSC-2018-008. SPSC-P330-ADD-10